Base Load Power Hub (BLPH)

BLPH Platform – Structural Verification Against Accidental Loads

Document Number: 123A90-DDL-ST-RE-90120

Document Class: 3

02	07/02/2025	Issue for Information (IFI)	F.Biancheri	A.Balzarotti	D.LoSterzo
01	08/01/2025	Issue for Information (IFI)	A.Aksoy	A.Balzarotti	D.LoSterzo
00	19/04/2024	Issue for Information (IFI)	A.Aksoy	A.Balzarotti	D.LoSterzo
Rev.	Date	Description	Prepared	Reviewed	Approved

TECON

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

Revision / Change Log

Rev.	Description
00	Issue for Information (IFI)
01	Issue for Information (IFI)
02	Issue for Information (IFI)

HOLDS LIST

No.	Description
1	
2	
3	
4	

Table of contents

1 INTRODUCTION 7
1.1 PROJECT OVERVIEW 7
1.1.1 Project Location 7
1.1.2 Project Concept 8
2 DOCUMENT SCOPE 10
3 REFERENCES 11
3.1 CODES AND STANDARDS 11
3.2 COMPANY SPECIFICATIONS 12
3.3 PROJECT DOCUMENTS 12
3.4 SOFTWARE 12
4 DEFINITIONS AND ABBREVIATIONS 13
5 SUMMARY AND CONCLUSIONS 15
6 DESIGN DATA 16
7 MATERIALS 17
7.1 STRUCTURAL STEEL PROPERTIES 17
7.2 PLATING 18
7.3 GRATING 18
8 DESIGN CRITERIA AND REQUIREMENTS 19
8.1 GENERAL 19
8.2 PARTIAL RESISTANCE FACTORS 20
8.2.1 Partial Resistance Factors for Tubular Sections: 20
8.2.2 Partial Resistance Factors for Non-tubular Sections 20
8.2.3 Partial Resistance Factors for Tubular Joints Check 21
8.2.4 Partial Resistance Factors for Accidental Limit State Actions 21
8.3 LOAD CLASSIFICATIONS 22
8.4 PARTIAL ACTION FACTORS 23
8.4.1 Partial Action Factors for In-Service Analysis 23

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

8.4.2 Partial Action Factors for Serviceability Limit States 23
8.4.3 Partial Action Factors for Accidental Limit States 23
8.5 ACCEPTANCE CRITERIA 23
9 DROPPED OBJECT 24
9.1 LAYDOWN AREA AT EL. +23.310 M 24
9.1.1 HEA340 – 4000 mm 26
9.2 LAYDOWN AREA AT EL. +30.310 M 30
9.2.1 HEA340 – 6000 mm 32
10 SHIP IMPACT 36
11 FIRE and BLAST LOAD 37
11.1 JET FIRE LOAD 37
11.1.1 Basic load cases and combinations 38
11.1.2 Results for the Static Checks 39
11.1.3 Qualitative discussion on H2 vessel saddles 50
11.2 BLAST CHECK 53
11.2.1 Plan at elevation +30.310 – primary beams 53
11.2.2 Plan at elevation +30.310 – secondary beams 56
11.2.3 Floor Plates 58
11.3 BLAST CHECK - ADDITIONAL STRUCTURAL CHECK 58
11.3.1 Load cases and combinations 59
11.3.2 Load combinations 62
11.3.3 Results from the static checks 63
11.4 DYNAMIC SIMULATION 67
11.4.1 Mode shapes and mass participation 69
11.4.2 Dynamic Response 71
APPENDIX A ALARP WORKSHEET 73

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

List of Figures

Figure 1.1 HOLLANDSE KUST NOORD WIND PARK Location Map 7
Figure 1.2 - Wind Park Details 8
Figure 1.3 – BLPH Concept 8
Figure 9.1 – Elevation 23.310 LAT – Lower deck Laydown area detail 24
Figure 9.2 – Elevation 23.310 LAT – Lower deck with Laydown area 25
Figure 9.3 – Elevation 30.310 LAT – Upper deck Laydown area detail. 30
Figure 9.4 – Elevation 30.310 LAT – Upper deck with Laydown area. 31
Figure 11.1 -Primary Beams checked at El. +30.310m - UD 54
Figure 11.2 - Secondary beams checked at el. +30.31 m 56

List of tables

Table 4.1 - Definitions and Abbreviations 14
Table 7.1 - Material Selection, Ref /24/ 17
Table 7.2 – Mechanical properties of Plates 18
Table 7.3 – Mechanical properties of Structural Seamless Tubulars 18
Table 7.4 – Mechanical properties for Structural Sections 18
Table 8.1- Resistance Factors for Tubular Sections 20
Table 8.2- Resistance for Non Tubular Section 20
Table 8.3 - Resistance Factors for Tubular Joints 21
Table 8.4 - ISO Loads Classification 22
Table 8.5 – Partial Action Factors for the In-Service Analysis 23
Table 9.1 – Dropped object verification – 3.5t from 5m over 1 beam 27
Table 9.2 – Dropped object verification – 5t from 5m over 2 beams 29
Table 10.1 - Topsides Accelerations and Displacements from Ship Impact 36
Table 11.1 – Unfactored Load combinations from Ref. /25/ 38
Table 11.2 - Superimposed area loads for local checks 53
Table 11.3 – PG 1000x400x15x25 – L=16m 55
Table 11.4 – PG 1000x300x15x25 – L=12m 55
Table 11.5 - IPE240 – A – 4000mm 57

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

Table 11.6 - IPE330 – B – 4000mm 57
Table 11.7 – 8mm thk PLATE 58

List of Attachments

A ALARP work sheet

1 INTRODUCTION

1.1 PROJECT OVERVIEW

Crosswind, a Shell and Eneco joint venture, was awarded the tender to develop the offshore Hollandse Kust Noord (HKN) wind farm, located 18.5km off the coast of Netherlands near the town of Egmond aan Zee. The consortium plans to have HKN operational in 2023 with an installed capacity of 759MW generating at least 3.3TWh per year. This is sufficient renewable power to supply more than 1 million Dutch households with green electricity.

Offshore wind farms produce intermittent electricity and balancing these dips and peaks and integrating this electricity into the national energy system requires new technologies. For this reason, the offshore wind farm will include several new technologies that could be implemented at full-scale in the future. The new technologies being explored include a floating solar park, a short-duration battery storage as well as long-term storage via green hydrogen produced by water electrolysis and subsequently consumed in a fuel cell. The combination of these individual measures, herein referred to as the Base Load Power Hub (BLPH) will ensure a continuous power supply regardless of the wind situation.

1.1.1 Project Location

The Hollandse Kust Noord (HKN) wind farm is located 18.5km off the coast of the Netherlands near the town of Egmond aan Zee.

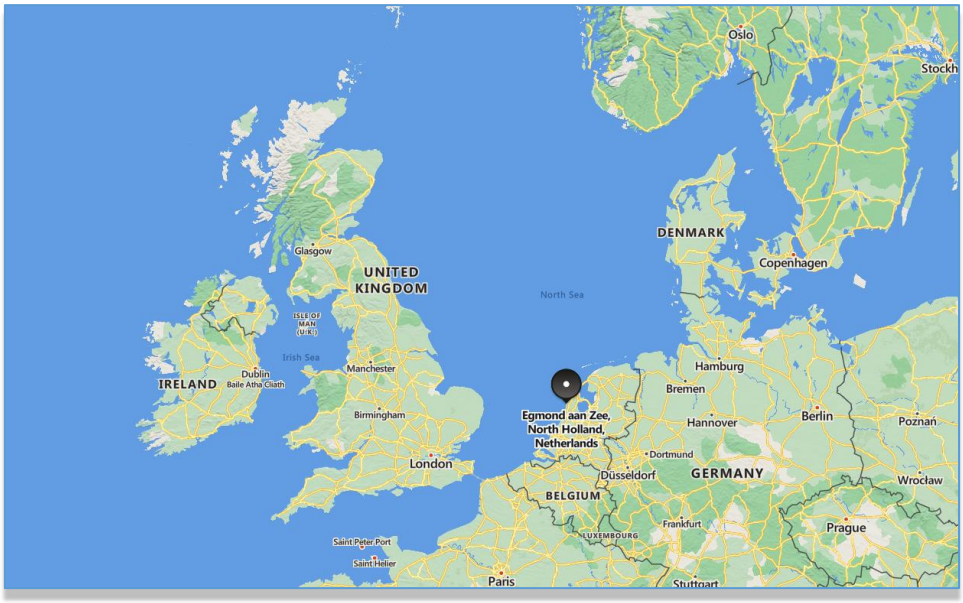


Figure 1.1 HOLLANDSE KUST NOORD WIND PARK Location Map

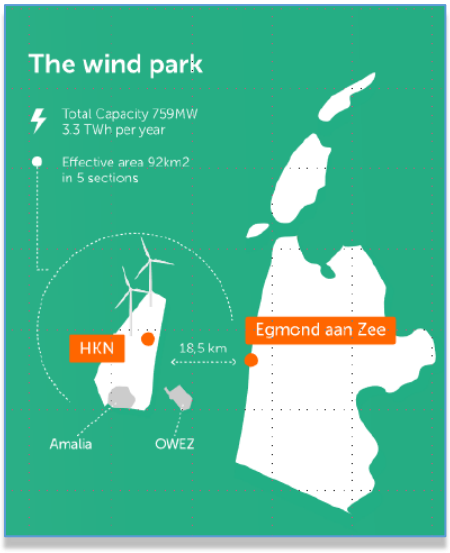


Figure 1.2 - Wind Park Details

The wind farm consist of No. 69 x 11.5MW wind turbine generators each to be installed on a dedicated monopile structure. A 70th monopile located on coordinates E 590719.1, N 5841602.3 is reserved for installing the platform accommodating the BLPH. The monopile structure was designed and installed by Van Oord Offshore Wind (VooW) and therefore not part of the BLPH scope.

1.1.2 Project Concept

All components included in the BLPH will be integrated onshore on a topsides and installed in an offshore location within the boundaries of the HKN wind farm. At its simplest, the BLPH will store energy during periods of high electricity generation from renewable sources (a wind turbine generator and the floating solar PV farm) and release it during periods of low generation. In practice. It is expected that the energy stored will supplement generation from renewable sources to ensure that at least 1.0MW of power is exported to the electrical grid regardless of wind/solar availability.

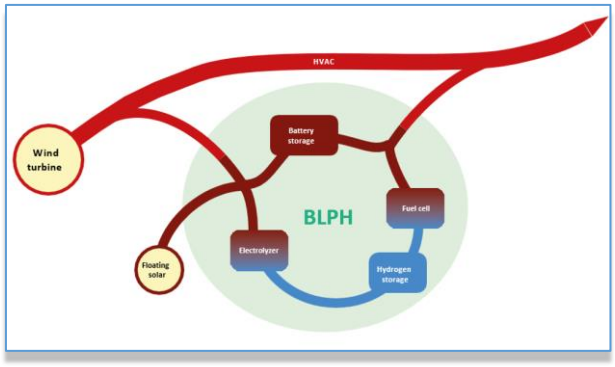


Figure 1.3 – BLPH Concept

Electricity in the BLPH will be stored in the form of electrons in a battery energy storage system (BESS) as well as converted into green hydrogen via water electrolysis. When the power output from the connecting wind turbine drops to below 1 MWe, the BLPH will return its stored energy to supplement the remaining power output. This will be by discharging the BESS, while stored hydrogen will be converted back into electricity using a fuel cell to extend the discharge duration.

The purpose of the BLPH s to function as a testbed for the integration of energy storage technologies with renewable generation. It is expected that equipment installed on the BLPH will operate as Normally Unmanned Installation for at least two (2) years with no or minimal maintenance and it will have its own independent control room with the ability to communicate with Crosswind's control room.

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

2 DOCUMENT SCOPE

The objective of this report is to present the results of the BLPH platform structural verification against accidental loads.

In detail, it covers the check of Dropped object on Laydown areas, Blast and fire load and ship impact. The analysis has been performed in compliance with the requirements, criteria and parameters reported in the Structural Design Premises, Ref./20/.

All structural analyses have been carried out using the structural analysis program SACS, the proprietary software developed by Bentley, Ref. /29/.

The International System of Units (SI) has been used in all engineering assessments and calculations.

Structural Code checks are performed according to BD EN ISO 19902 for tubular members and tubular joints, Ref./7/, and according to Eurocode 3 for non-tubular structural elements, Ref./9/.

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

3 REFERENCES

3.1 CODES AND STANDARDS

Doc. No.	Description
/1/ BS EN ISO 19900	General requirements for offshore structures - 2019
/2/ BS EN ISO 19901-1	Specific requirements for offshore structures - Part 1: Metocean design and operating considerations - 2015
/3/ BS EN ISO 19901-2	Seismic design procedures and criteria
/4/ BS EN ISO 19901-3	Specific requirements for offshore structures – Part 3: Topsides structure - 2014
/5/ BS EN ISO 19901-5	Specific requirements for offshore structures – Part 5: Weight Management - 2021
/6/ BS EN ISO 19901-6	Specific requirements for offshore structures – Part 6: Marine Operations – 2009
/7/ BS EN ISO 19902	Petroleum and natural gas industries - Fixed steel offshore structures – 2020
/8/ ISO 19906:2019	Petroleum and natural gas industries — Arctic offshore structures
/9/ UNI EN 1993-1-1	Design of steel structures - Part 1-1: General rules and rules for buildings
/10/ API RP 2A-WSD	Recommended practice for planning, designing and constructing fixed offshore platforms – Working stress design – 22nd edition – 2014
/11/ DNV-ST-N001	DNV GL - Marine operation and marine warranty - 2021
/12/ EN 1991-1-3:2003 & A1:2015	EN, Eurocode 1 – Actions on Structures – Part 1-3: General actions – Snow loads - Incorporating corrigenda December 2004 and March 2009, December 2015.
/13/ DNV-ST-0145	DNV, Offshore substations
/14/ DNV-RP-C201	DNV, Buckling Strength of Plated Structures, October 2010.
/15/ DNV-RP-C204	DNV Design against accidental loads – 2019
/16/ DNV-RP-C205	DNV GL - Environmental conditions and environmental loads - September 2019, amended September 2021.

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

3.2 COMPANY SPECIFICATIONS

Doc. No.	Description
/17/ DEP 37.19.00.12	Gen - Offshore Topsides Structures
/18/ DEP 37.19.00.30	Gen - Fixed Steel Offshore Structures (Adoption of IOGP S-631-11, Amendments / Supplements to ISO 19902:2020).
/19/ DEP 37.81.10.19	Gen - Marine Operations Requirements – Loadout, Transportation and Installation of Offshore Structures (Amendments / Supplements to ISO 19901-6)

3.3 PROJECT DOCUMENTS

Doc. No.	Description
/20/ 123A90-DDL-ST-SP-90017	Structural Design Basis
/21/ 123A90-DDL-MD-RE-01006	Monthly Weight Report
/22/ 123A90-DDL-PP-DS-70070	Plot Plans
/23/ Pending	Handling Philosophy Report
/24/ 123A90-DDL-ST-SP-90018	Structural Material Specification for Topside and TP
/25/ 123A90-DDL-ST-RE-90000	BLPH Platform – In service analysis report
/26/ 123A90-DDL-ST-RE-90006	BLPH Platform – Secondary Structures Design Report
/27/ 123A90-DDL-SAF-RE-30020	Fire and Explosion Risk Analysis (FERA) – Rev 03
/28/ 123A90-DDL-ST-TN-90119	Evaluating ISO and DNV approaches

3.4 SOFTWARE

Doc. No.	Description
/29/ SACS	Structural Analysis Computer System – BENTLEY Inc- v15

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

4 DEFINITIONS AND ABBREVIATIONS

COMPANY or Client (CPY)	Crosswind
CONTRACTOR (CTR)	ROSETTI MARINO S.p.A.
PROJECT	HOLLANDSE KUST NOORD WIND PARK Project
T&I CONTRACTOR	DEME
ALARP	As Low As Reasonably practicable
ALS	Accidental Limit State
BEB	Best Estimate Bathymetry
BESS	BATTERY ENERGY STORAGE SYSTEM
BG	Box Girder
BLPH	Base Load Power Hub
Ce	Snow Exposure Coefficient
CF	Caisson Frame
CL	Concentrated Load
CoG	Centre of Gravity
CTV	Crew Transfer Vessel
CW	CrossWind
DAF	Dynamic Amplification Factor
DFF	Damage Fatigue Factors
DLB	Ductility Level Blast
DNV	Det Norske Veritas
DOP	Dropped Object Protection
DP	Dynamic Positioning
El.	Elevation
EPCI	Engineering Procurement Construction and Installation
FEED	Front End Engineering Design
HAT	Highest Astronomical Tide
HKN	Hollandse Kust Noord
ICCP	Impressed Current Corrosion Protection

LAT	Lowest Astronomical Tide
LRFD	Load and Resistance Factor Design
MSL	Mean Sea Level
NTE	Not-to-Exceed
OD	Outside Diameter
PAU	Pre-Assembled Unit (H2 Vessels)
PG	Plate Girder
SCE	Safety Critical Equipment
T&I	Transport & Installation
ToS	Top of Steel
TP	Transition Piece
SLB	Strength Level Blast
UC	Unity Check
UDL	Uniformly Distributed Load
VIV	Vortex Induced Vibration
VOOW	Van Oord Offshore Wind
WTG	Wind Turbine Generator
W2W	Walk to Work

Table 4.1 - Definitions and Abbreviations

5 SUMMARY AND CONCLUSIONS

The analyses performed show that the BLPH platform is adequate to withstand the loads occurring during its operational life.

Local checks and redundancy check of the members were performed, refer to dedicated sections for all the results, in accordance with the requirements of Design Basis report, Ref. /20/ and with reference to the ALARP memo included in Appendix A.

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

6 DESIGN DATA

Design Data are taken from Ref. /20/, ref. section 9.2.5.

7 MATERIALS

7.1 STRUCTURAL STEEL PROPERTIES

For the structural analyses, steel types and grades to be used for the platform structures are summarised in Table 7.1 and specified in Ref. /24/. The material selection criteria are based on the requirements of ISO 19906:2019, ISO 19902:2020 and ISO 19901-3:2014. The materials are in accordance with the EN standard 10225:2019 and 10025:2019 and are suitable for plates, rolled sections and welded / seamless tubulars.

			EN10025-3	ISO EN 19902:2020						
Design Class	**Complexity**	**SQL**	**Hot rolled bar**	**Plates and Welded Tubular**	**Sections**	**SMLS pipes**	**THK**	**CVN inpact test**	**Material Designation**	**List of Options (EN10225-1 to -4) & EN10025-3**
DC1 TP to monopile flange connection	High	I (Z properties)	EN 10025 S420 NL	NA	NA	NA	t > 50	-40	DC1-I-420-40_Z	1, 2, 3, 4, 6, 12, 18, 24, 30
DC1 Complex lift-nodes and element connection to topside, Lift points, main complex joints	High	I (Z properties)	NA	EN 10225 S420 QLO / ML	NA	NA	25 < t <= 50	-40	DC1-I-420-40_Z DC1-I-460-40_Z	2, 7, 8, 11, 12, 17, 18
							t > 50	-40		
DC2 simple joints, primary deck girders and beams of Topside and TP, column and diagonal to lift points, main columns, Davit crane support, Bolts	Low	II	NA	EN 10225 S420 QLO / MLO	NA	NA	t < = 12	0	NA	-
							12 < t <= 25	-20	DC2-II-420-20 / DC2-II-460-20	2, 7, 8, 11 17 for t > 40mm
							25 < t <= 50	-40	DC2-II-420-40 DC2-II-460-40	
							t > 50	-40		
DC3 all other columns and diagonals, stiffeners, Secondary deck beams, Grillage and sea fastening	High	II	NA	EN 10225 S355 NLO / MLO	EN 10025 S355 MLO	EN 10225 S355 NLHHO / QLHHO API 5L X52	t < = 12	0	DC3-II-355-0 / DC3-II-X52-0	2, 7, 8 11 for plate 17 for t > 40mm
							12 < t <= 25	-20	DC3-II-355-20 / DC3-II-X52-20	
							25 < t <= 50	-40	DC3-II-355-40 / DC3-II-X52-40	
							t > 50	-40		
DC4 Equipment and vessel supports, modules supports, equipment fixing bolts	Low	III	NA	EN 10025 S355 J2	EN 10025 S355 J2	API 5L X52 EN 10210 S355 J2H	t < = 12	0	DC4-III-355-0 / DC4-III-X52-0 / DC4-III-X60-0	-
							12 < t <= 25	0		
DC5 floor plating, grating, Walkw ays, stairs, handrails	Any	IV	NA	EN 10025 S235 JR EN 10025 S275 J0 EN 10025 S355 J0	EN 10025 S235 JR EN 10025 S275 J0 EN 10025 S355 J0	API 5L Gr.B EN 10210 S235 JRH / EN 10210 S275 J0H / EN 10210 S355 J0H	t < = 12	10	DC5-IV-235-10 / DC5-IV-275-10 / DC5-IV-355-10 / DC5-IV-GRB-10	-
							12 < t <= 25	10		

Table 7.1 - Material Selection, Ref /24/

Mechanical properties for structural materials are presented in Table 7-2, Table 7-3 and Table 7-4.

- Young's Modulus = 205,000 N/mm^2
- Density = 7850 kg/m^3
- Poisson's Ratio = 0.3

Thickness (mm)	Min. Tensile Strength (N/mm^2)	Min. Yield Strength (N/mm2)	Steel Type (1)
t ≤ 16	500	420	I & II
16 < t ≤ 40	500	400	I & II
40 < t ≤ 63	480	390	I & II

63 < t ≤ 100	480	380	I & II
Note: 1) Type I steel has Z (through the thickness) properties.			

Table 7.2 – Mechanical properties of Plates

Thickness (mm)	Min. Tensile Strength (N/mm²)	Min. Yield Strength (N/mm2)	Steel Type
t ≤ 20	460	355	III
20 < t ≤ 40	460	345	III

Table 7.3 – Mechanical properties of Structural Seamless Tubulars

Thickness (mm)	Min. Tensile Strength (N/mm2)	Min. Yield Strength (N/mm2)	Steel Type
t ≤ 16	460/	355/2	IV
16 < t ≤ 40	460	345	IV

Table 7.4 – Mechanical properties for Structural Sections

7.2 PLATING

Plate thicknesses for primary structural steel starts at a minimum of 10 mm and increase in 5 mm steps Secondary steel lower and upper deck plates are 8 mm thick and 10mm for laydown areas for Dropped Object Protection (DOP).

Blast walls are not to be provided on a hydrogen processing facility, as free ventilation and free explosion venting is more important, and supportable, than obstruction walls.

7.3 GRATING

Grating is characterized by bearing bars 30 mm x 5 mm and mesh 30 mm x 50 mm.

8 DESIGN CRITERIA AND REQUIREMENTS

8.1 GENERAL

Structures in SOW is designed in accordance with limit states approach of ISO codes 19901 and 19902, Refs./2/, /4/and /7/. For non-tubular sections, Eurocode, Ref./9/, is adopted. Member forces and moments derived from the global analyses are used for checking member strength and stability, and joint strength.

The following limit states are defined and satisfied by the In-Service design:

- the Serviceability Limit State (SLS), corresponding to the criteria applicable to normal use or durability;
- the Ultimate Limit State (ULS), corresponding to the ultimate capacity for carrying loads;
- the Accidental Limit State (ALS) corresponding to damage due to an accidental event;

The general requirement of ISO code is that, for the structure as a whole and for each component, the following is satisfied:

$$R_d = \frac{R_k}{\gamma_M} > \gamma_F F_r = F_d$$

Where:

- R_d is the design resistance;
- R_k is the characteristic resistance;
- γ_M is the partial resistance factor reported in section 0;
- F_d is the design value of action;
- F_r is the characteristic value of action;
- γ_F is the partial action factor reported in Sec.8.4.

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

8.2 PARTIAL RESISTANCE FACTORS

8.2.1 Partial Resistance Factors for Tubular Sections:

The partial resistance factors for tubular sections from ISO 19902, Ref./7/, are listed below.

Resistance factor	Value	Definition
$\gamma_{R,t}$	1.05	Partial resistance factor for axial tensile strength
$\gamma_{R,c}$	1.18	Partial resistance factor for axial compressive strength
$\gamma_{R,b}$	1.05	Partial resistance factor for bending strength
$\gamma_{R,v}$	1.05	Partial resistance factor for shear strength
$\gamma_{R,h}$	1.25	Partial resistance factor for hoop buckling strength

Table 8.1- Resistance Factors for Tubular Sections

8.2.2 Partial Resistance Factors for Non-tubular Sections

The partial resistance factors for non-tubular sections from Eurocode 3, Ref./9/, are listed below.

Resistance factor	Value	Definition
Resistance of members and cross sections		
γ_{M0}	1.10	Cross-section resistance to excessive yield strain including local buckling
γ_{M1}	1.10	Resistance of unstable elements measured during element inspection
γ_{M2}	1.25	Tensile cross-section resistance to mechanical breakdown
Resistance of connections		
γ_{M2}	1.25	Bolts, rivets, pins, welds and slabs on supporting surface
γ_{M3}	1.25	Sliding resistance at Ultimate Limit State Category C
$\gamma_{M3,SER}$	1.10	Sliding resistance at Serviceability Limit State
γ_{M4}	1.10	Injection bolt collapse resistance
γ_{M5}	1.10	Resistance of connections in open lattice trusses
$\gamma_{M6,SER}$	1.00	Resistance of pins at Serviceability Limit State
γ_{M7}	1.10	Preload of high strength bolts

Table 8.2- Resistance for Non Tubular Section

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

These resistance factors apply to the design of members and are not applicable to local details, such as padeyes. Reference should be made to ISO 19902 for a full listing of partial resistance factors and to Eurocode 3, Ref./9/, for welds and bolts design resistance factors.

8.2.3 Partial Resistance Factors for Tubular Joints Check

The partial resistance factors for tubular joints checks are provided in following table.

Resistance factor	Value	Definition
$\gamma_{R,j}$	1.05	Partial resistance factor for joints
$\gamma_{z,j}$	1.17	Additional partial resistance factor for members during joint pre-strain collapse

Table 8.3 - Resistance Factors for Tubular Joints

8.2.4 Partial Resistance Factors for Accidental Limit State Actions

All partial resistance factors for the abnormal / accidental limit state conditions are set equal to 1.00.

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

8.3 LOAD CLASSIFICATIONS

Design loads are classified as either global or local within ISO 19901-3, Ref. /4/ and ISO 19902, Ref./7/ and summarized in Table 8.4.

Load Type	ISO Designation	Description
Permanent (Dead)	G1	Structure self-weight; Equipment & piping dry weight; Any actions due to misalignment of structures such as between the topside and TP
Permanent (Dead)	G2	permanent action imposed on the topsides structure by self-weight of equipment and other objects that remain constant for long periods of time, but which can change from one mode of operation to another, or during a mode of operation, bulk loads
Variable (Live)	Q1	Equipment & piping contents weight; Superimposed area loads; Ice and snow accretions
Variable (Live)	Q2	Crane hook loads; Liquids in pipes and process vessels for pressure testing; Machine operations
Environmental (extreme)	Ee	Extreme quasi-static action due to wind, waves and current (eg.100-yr storm wind)
Environmental (operational)	Eo	1-yr storm wind
Inertial Response (operational)	Do	Equivalent quasi-static action representing dynamic response caused by the Eo wave condition
Inertial Response (extreme)	Do	Equivalent quasi-static action representing dynamic response caused by the Ee wave condition
Pressure (accidental)	-	Blast
Inertial (accidental)	-	Ship impact on monopile
Impact Energy (accidental)	-	Dropped Object
Transient	T	Transient Loads for Pre-Service Analyses

Table 8.4 - ISO Loads Classification

8.4 PARTIAL ACTION FACTORS

8.4.1 Partial Action Factors for In-Service Analysis

Partial action factors to be applied for the operating conditions in compliance with ISO codes are reported in Table 8.5.

Load combination		Dead load		Live load		Environmental load	Wave dynamics
		G1	G2	Q1	Q2	Eo / Ee	Do / De
		$\gamma_{f,G1}$	$\gamma_{f,G2}$	$\gamma_{f,Q1}$	$\gamma_{f,Q2}$	$\gamma_{f,Eo}$ / $\gamma_{f,Ee}$	$\gamma_{f,D}$
Operating Gravity / Buoyancy		1.3	1.3	1.5	1.5	-	-
Operating Storm		1.3	1.3	1.5	1.5	1.22	1.25
Extreme Storm (100 years)	Max Compression	1.0	1.0	1.0	-	1.35	1.25
	Max Tension	0.9	0.9	0.8	-	1.35	1.25

Table 8.5 – Partial Action Factors for the In-Service Analysis

8.4.2 Partial Action Factors for Serviceability Limit States

All partial action factors for Serviceability Limit States conditions are set equal to 1.0.

8.4.3 Partial Action Factors for Accidental Limit States

All Partial Resistance Factors for Accidental Limit States conditions are set equal to 1.0.

8.5 ACCEPTANCE CRITERIA

The maximum member Unity Check (UC) will be less than unity.

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

9 DROPPED OBJECT

This section presents the structural check for laydown area beams against dropped object. The checks are performed according to DNV-RP-C204, Ref. /15/, considering the following data, taken from Design basis report, ref. /20/:

Small container	1.25m x1.25m	weight 3.5t	drop height 5m;
Medium container	2.00m x 2.50m	weight 5.0t	drop height 5m.

Considering the beam spacing, the small container is considered involving one beam, while two beams are involved by the drop of medium container.

9.1 LAYDOWN AREA AT EL. +23.310 M

The following figure shows the considered area at elevation 23.310m. HEA340 beams (length 4000mm) are present in this laydown area at elevation lower deck.

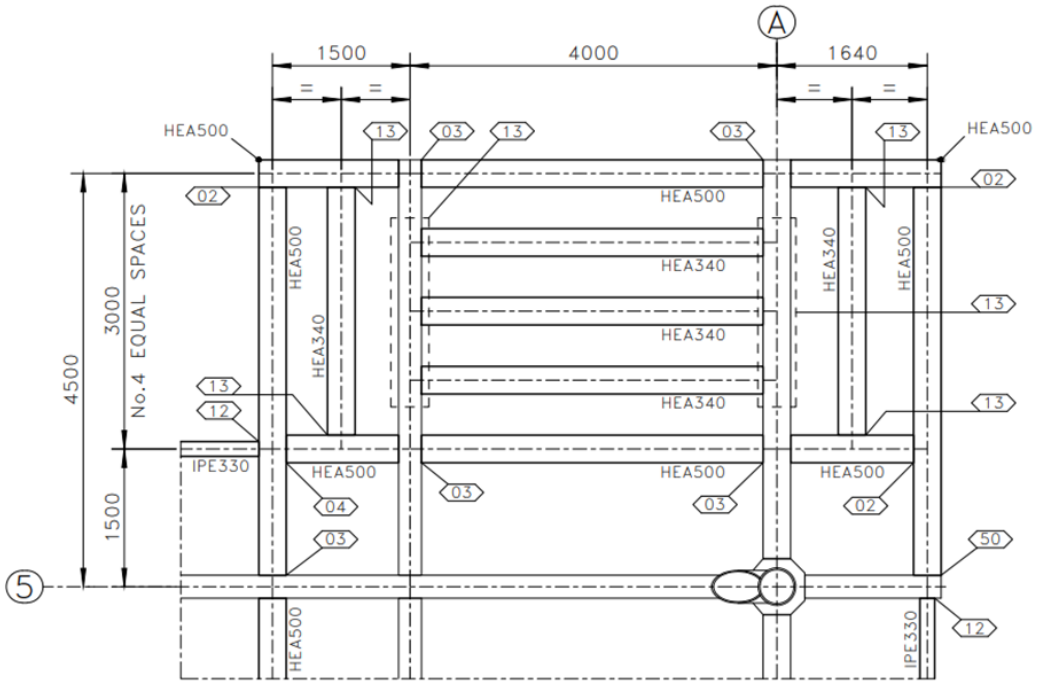


Figure 9.1 – Elevation 23.310 LAT – Lower deck Laydown area detail

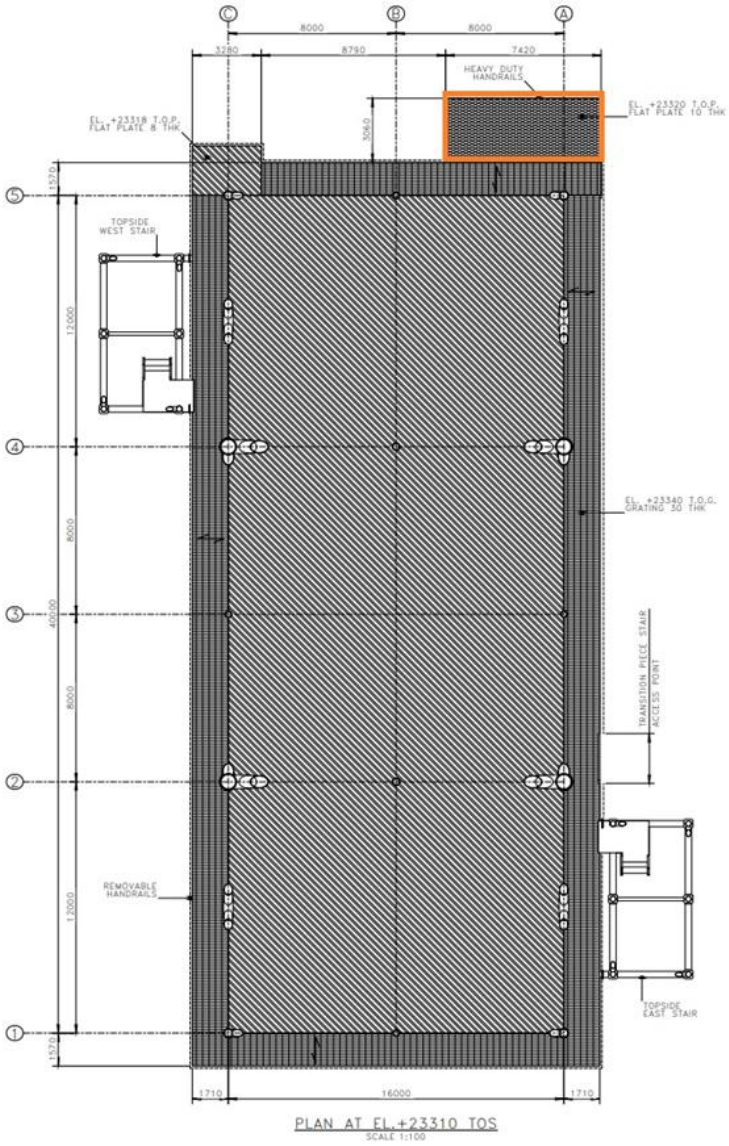


Figure 9.2 – Elevation 23.310 LAT – Lower deck with Laydown area

9.1.1 HEA340 – 4000 mm

DROPPED OBJECT CHECK - DNV-RP-C204 Ed. Sept 2019, amended Sept 2021				
VARIABLE	**VALUE**	**UNIT**	**DNV REFERENCE**	**DESCRIPTION**
Material Properties				
E	205000	MPa		Young modulus
f_y	355	MPa		Yield strength
Beam Properties				
Profile	HE340A			Section
Symmetry	Y			Y = symmetrical profile, S = stiffened, N = unsymmetrical profile
h	330	mm		Beam overall height (buckling check only)
h_w	243	mm		Web height (buckling check only)
b_f	300	mm		Flange width (buckling check only)
t_w	9.5	mm		Web thickness (buckling check only)
t_f	16.5	mm		Flange thickness (buckling check only)
t_{plate}	10	mm		Plate thickness (buckling check only)
$t_f + t_{plate}$	26.5	mm		Flange + Plate thickness (buckling check only)
r	27	mm		Radius
A	133.5	cm^2		Cross section area
A_w	29.83	cm^2		Section shear area
$W_{el,y}$	1678	cm^3		Elastic section modulus
$W_{pl,y}$	1850	cm^3		Plastic section modulus
M_p	657	kNm		Plastic bending moment
Beam Information				
L	4000	mm		Beam span
Type	1			Cross sectional type (DNV-OS-C101)
C_v	1.0			Shear coefficient
c_1	1.0			Restrain factor (2 = clamped ends, 1 = pinned ends)
w_c	166	mm		Characteristic deformation for plating
d_c	330	mm		Characteristic dimension for local buckling
Dropped Object Energy (DNV Sect. 4.3)				
W	3.5	t		Weight
	34.335	kN		
s	5	m		Travelled distance from drop point
g	9.81	m/s^2		
n	1			Number of impacted beams
v	9.90	m/s	(4.3)	Velocity for impacts in air
E_{kin}	171.675	kNm	(4.1)	Kinetic energy for objects falling in air (total)
E	171.675	kNm		Impact energy on each beam
Stiffeners Factors				
k_{beam}	1.37E+06	kN/m		Beam axial stiffness
k_{node}	1.00E+00	kN/m		Node axial stiffness (the considered member assumed removed)
1/k	1.00E+00		(3.9)	
k	1.00E+00	kN/m		Equivalent axial stiffness
c	5.83E-06			Non-dimensional spring stiffness
c_f	5.81E-06		(3.21)	Axial flexibility factor
kl	0.5			Smaller distance from location of collision load to adjacent joint (kl ≤ 0.5l)

Local Buckling - Max Deflection (DNV Sect. 3.10.2)			
β_{max}	1.02	(3.19)	Max slenderness ratio (buckling not to be considered if $\beta \le \beta_{max}$)
Flange	1		Check considered (1 = yes, 0 = no)
β_f	34.79	(3.24/3.25)	Flange slenderness ratio
	β > βmax - Buckling required		
w_{bf}	358 mm	(3.22)	Max deflection - Flange buckling
Web	1		Check considered (1 = yes, 0 = no)
β_w	22.01	(3.26/3.27)	Web slenderness ratio
	β > βmax - Buckling required		
w_{bw}	1413 mm	(3.22)	Max deflection - Web buckling
Tensile fracture in yield hinges - Max deflection (DNV Sect. 3.10.4)			
ε_{cr}	0.15	(Table 3-3)	Critical strain for rupture
H	0.0034	(Table 3-3)	Non-dimensional plastic stiffness
ε_y	0.0017		Yield strain
c_{lp}	0.209	(3.30)	Plastic zone length factor
c_w	7.296	(3.29)	Displacement factor
w_f	361 mm	(3.28)	Max deflection - Tensile fracture
Energy Check			
w_{max}	358 mm		Max allowable beam deflection = min (w_{bf}, w_{bw}, w_f)
~~w~~	2.152		Non-dimensional deformation
R_0	657 kN		Plastic collapse resistance in bending
R/R_0	1.00	(Figure 3-11)	With c = 0.00
R	657 kN		Plastic collapse resistance
$E_{allowable}$	234.99 kNm		Max absorbed energy
UC	**0.73 < 1.00**		**Unity Check = $E_{required}$ / $E_{allowable}$**
	Check ok		
Shear Check			
V	484 kN		Dynamic shear reaction
UC	**0.63 < 1.00**		**Unity Check = V / (0.60*1.20*f_y*A_w*C_v)**
	Check ok		

Table 9.1 – Dropped object verification – 3.5t from 5m over 1 beam

Calculation is repeated for medium container:

DROPPED OBJECT CHECK - DNV-RP-C204 Ed. Sept 2019, amended Sept 2021

VARIABLE	VALUE	UNIT	DNV REFERENCE	DESCRIPTION
Material Properties				
E	205000	MPa		Young modulus
f_y	355	MPa		Yield strength
Beam Properties				
Profile	HE340A			Section
Symmetry	Y			Y = symmetrical profile, S = stiffened, N = unsymmetrical profile
h	330	mm		Beam overall height (buckling check only)
h_w	243	mm		Web height (buckling check only)
b_f	300	mm		Flange width (buckling check only)
t_w	9.5	mm		Web thickness (buckling check only)
t_f	16.5	mm		Flange thickness (buckling check only)
t_{plate}	10	mm		Plate thickness (buckling check only)
$t_f + t_{plate}$	26.5	mm		Flange + Plate thickness (buckling check only)
r	27	mm		Radius
A	133.5	cm^2		Cross section area
A_w	29.83	cm^2		Section shear area
$W_{el,y}$	1678	cm^3		Elastic section modulus
$W_{pl,y}$	1850	cm^3		Plastic section modulus
M_p	657	kNm		Plastic bending moment
Beam Information				
L	4000	mm		Beam span
Type	1			Cross sectional type (DNV-OS-C101)
C_v	1.0			Shear coefficient
c_1	1.0			Restrain factor (2 = clamped ends, 1 = pinned ends)
w_c	166	mm		Characteristic deformation for plating
d_c	330	mm		Characteristic dimension for local buckling
Dropped Object Energy (DNV Sect. 4.3)				
W	5	t		Weight
	49.05	kN		
s	5	m		Travelled distance from drop point
g	9.81	m/s^2		
n	2			Number of impacted beams
v	9.90	m/s	(4.3)	Velocity for impacts in air
E_{kin}	245.25	kNm	(4.1)	Kinetic energy for objects falling in air (total)
E	122.625	kNm		Impact energy on each beam
Stiffeners Factors				
k_{beam}	1.37E+06	kN/m		Beam axial stiffness
k_{node}	1.00E+00	kN/m		Node axial stiffness (the considered member assumed removed)
1/k	1.00E+00		(3.9)	
k	1.00E+00	kN/m		Equivalent axial stiffness
c	5.83E-06			Non-dimensional spring stiffness
c_f	5.81E-06		(3.21)	Axial flexibility factor
kl	0.5			Smaller distance from location of collision load to adjacent joint (kl ≤ 0.5l)

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

Local Buckling - Max Deflection (DNV Sect. 3.10.2)			
β_{max}	1.02	(3.19)	Max slenderness ratio (buckling not to be considered if $\beta \leq \beta_{max}$)
Flange	1		Check considered (1 = yes, 0 = no)
β_f	34.79	(3.24/3.25)	Flange slenderness ratio
	β > βmax - Buckling required		
w_{bf}	358 mm	(3.22)	Max deflection - Flange buckling
Web	1		Check considered (1 = yes, 0 = no)
β_w	22.01	(3.26/3.27)	Web slenderness ratio
	β > βmax - Buckling required		
w_{bw}	1413 mm	(3.22)	Max deflection - Web buckling
Tensile fracture in yield hinges - Max deflection (DNV Sect. 3.10.4)			
ε_{cr}	0.15	(Table 3-3)	Critical strain for rupture
H	0.0034	(Table 3-3)	Non-dimensional plastic stiffness
ε_y	0.0017		Yield strain
c_{lp}	0.209	(3.30)	Plastic zone length factor
c_w	7.296	(3.29)	Displacement factor
w_f	361 mm	(3.28)	Max deflection - Tensile fracture
Energy Check			
w_{max}	358 mm		Max allowable beam deflection = min (w_{bf}, w_{bw}, w_f)
~~w~~	2.152		Non-dimensional deformation
R_0	657 kN		Plastic collapse resistance in bending
R/R_0	1.00	(Figure 3-11)	With c = 0.00
R	657 kN		Plastic collapse resistance
$E_{allowable}$	234.99 kNm		Max absorbed energy
UC	**0.52 < 1.00**		**Unity Check = $E_{required}$ / $E_{allowable}$**
	Check ok		
Shear Check			
V	480 kN		Dynamic shear reaction
UC	**0.63 < 1.00**		**Unity Check = V / (0.60*1.20*f_y*A_w*C_v)**
	Check ok		

Table 9.2 – Dropped object verification – 5t from 5m over 2 beams

9.2 LAYDOWN AREA AT EL. +30.310 M

The following figure shows the considered area at elevation 30.310m. HEA340 beams (length 6000mm) are present in this laydown area at elevation upper deck.

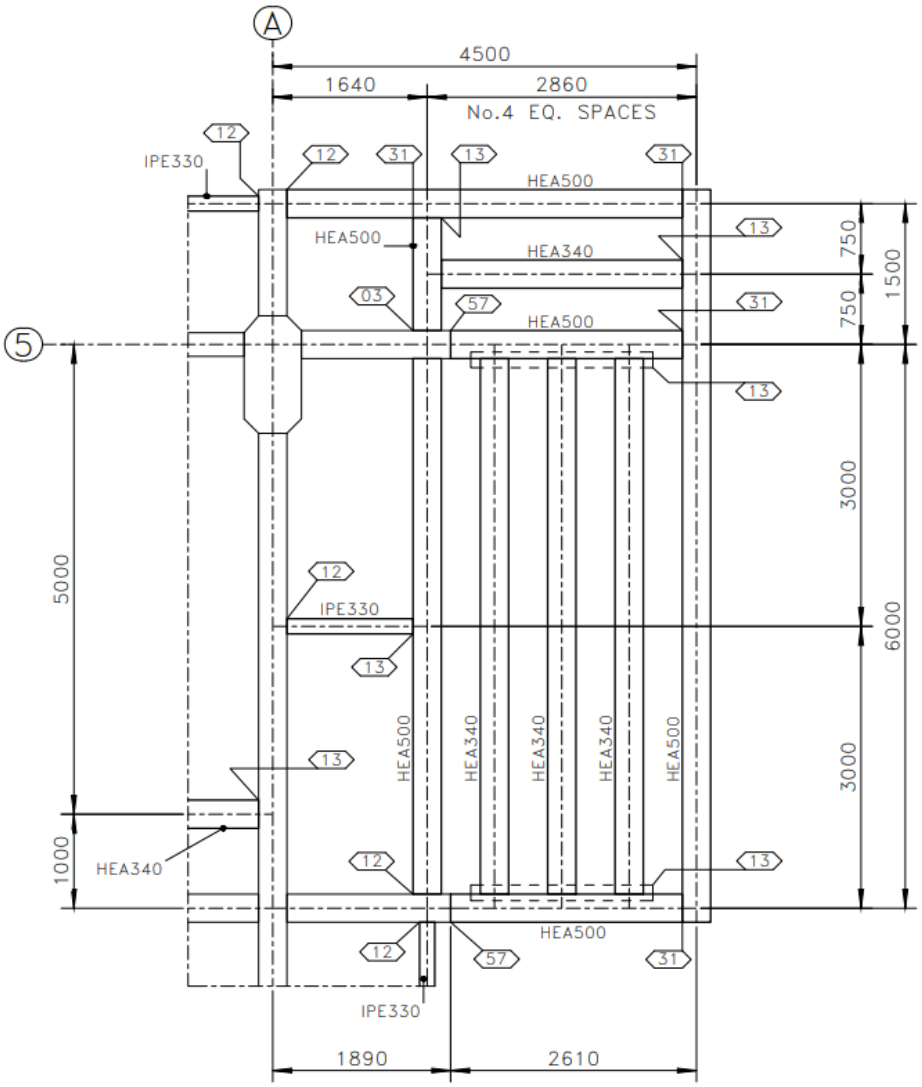


Figure 9.3 – Elevation 30.310 LAT – Upper deck Laydown area detail.

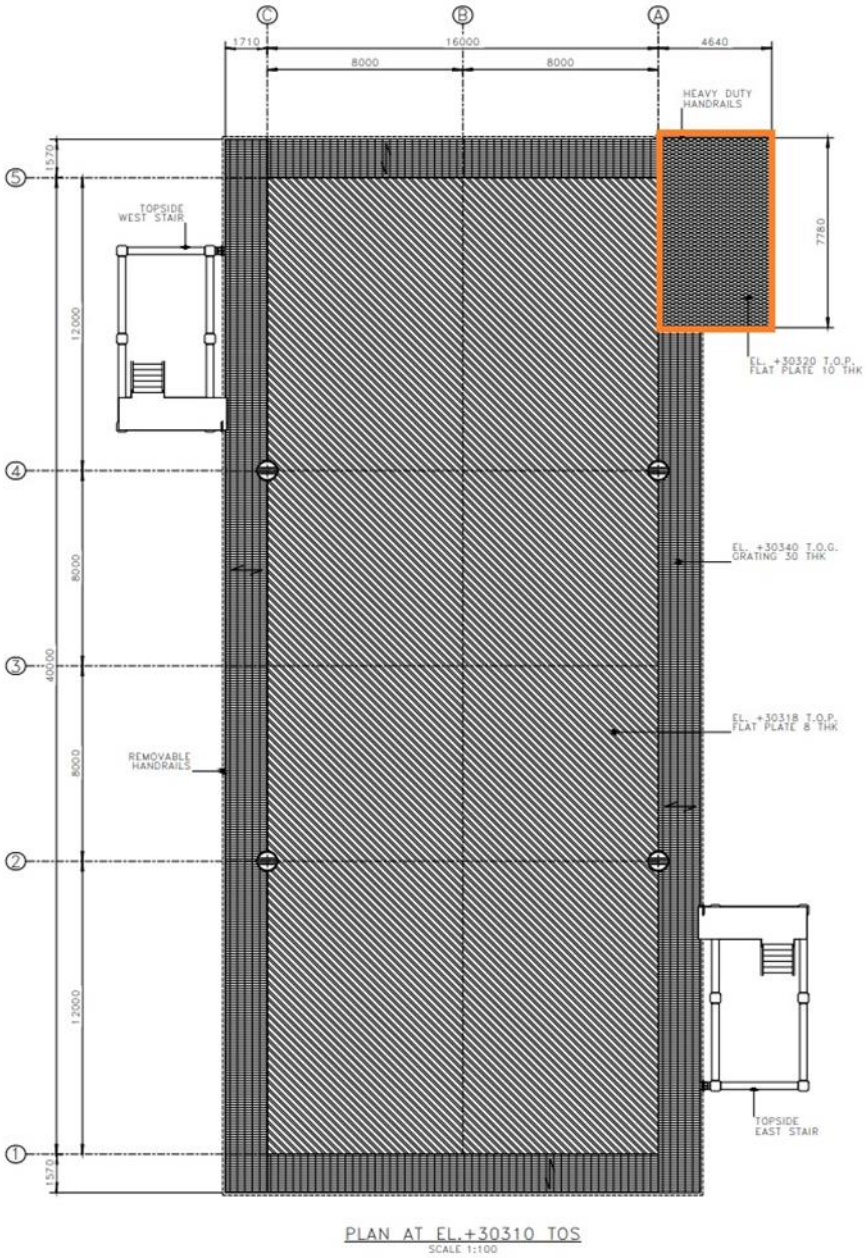


Figure 9.4 – Elevation 30.310 LAT – Upper deck with Laydown area.

9.2.1 HEA340 – 6000 mm

DROPPED OBJECT CHECK - DNV-RP-C204 Ed. Sept 2019, amended Sept 2021

VARIABLE	VALUE	UNIT	DNV REFERENCE	DESCRIPTION
Material Properties				
E	205000	MPa		Young modulus
f_y	355	MPa		Yield strength
Beam Properties				
Profile	HE340A			Section
Symmetry	Y			Y = symmetrical profile, S = stiffened, N = unsymmetrical profile
h	330	mm		Beam overall height (buckling check only)
h_w	243	mm		Web height (buckling check only)
b_f	300	mm		Flange width (buckling check only)
t_w	9.5	mm		Web thickness (buckling check only)
t_f	16.5	mm		Flange thickness (buckling check only)
t_{plate}	10	mm		Plate thickness (buckling check only)
$t_f + t_{plate}$	26.5	mm		Flange + Plate thickness (buckling check only)
r	27	mm		Radius
A	133.5	cm^2		Cross section area
A_w	29.83	cm^2		Section shear area
$W_{el,y}$	1678	cm^3		Elastic section modulus
$W_{pl,y}$	1850	cm^3		Plastic section modulus
M_p	657	kNm		Plastic bending moment
Beam Information				
L	6000	mm		Beam span
Type	1			Cross sectional type (DNV-OS-C101)
C_v	1.0			Shear coefficient
c_1	1.0			Restrain factor (2 = clamped ends, 1 = pinned ends)
w_c	166	mm		Characteristic deformation for plating
d_c	330	mm		Characteristic dimension for local buckling
Dropped Object Energy (DNV Sect. 4.3)				
W	3.5	t		Weight
	34.335	kN		
s	5	m		Travelled distance from drop point
g	9.81	m/s^2		
n	1			Number of impacted beams
v	9.90	m/s	(4.3)	Velocity for impacts in air
E_{kin}	171.675	kNm	(4.1)	Kinetic energy for objects falling in air (total)
E	171.675	kNm		Impact energy on each beam
Stiffeners Factors				
k_{beam}	9.12E+05	kN/m		Beam axial stiffness
k_{node}	1.00E+00	kN/m		Node axial stiffness (the considered member assumed removed)
1/k	1.00E+00		(3.9)	
k	1.00E+00	kN/m		Equivalent axial stiffness
c	3.89E-06			Non-dimensional spring stiffness
c_f	3.87E-06		(3.21)	Axial flexibility factor
kl	0.5			Smaller distance from location of collision load to adjacent joint (kl ≤ 0.5l)

Local Buckling - Max Deflection (DNV Sect. 3.10.2)				
β_{max}	1.17		(3.19)	Max slenderness ratio (buckling not to be considered if $\beta \leq \beta_{max}$)
Flange	1			Check considered (1 = yes, 0 = no)
β_f	34.79		(3.24/3.25)	Flange slenderness ratio
	β > βmax - Buckling required			
w_{bf}	805	mm	(3.22)	Max deflection - Flange buckling
Web	1			Check considered (1 = yes, 0 = no)
β_w	22.01		(3.26/3.27)	Web slenderness ratio
	β > βmax - Buckling required			
w_{bw}	3179	mm	(3.22)	Max deflection - Web buckling
Tensile fracture in yield hinges - Max deflection (DNV Sect. 3.10.4)				
ε_{cr}	0.15		(Table 3-3)	Critical strain for rupture
H	0.0034		(Table 3-3)	Non-dimensional plastic stiffness
ε_y	0.0017			Yield strain
c_{lp}	0.209		(3.30)	Plastic zone length factor
c_w	16.416		(3.29)	Displacement factor
w_f	813	mm	(3.28)	Max deflection - Tensile fracture
Energy Check				
w_{max}	805	mm		Max allowable beam deflection = min (w_{bf}, w_{bw}, w_f)
~~w~~	4.841			Non-dimensional deformation
R_0	438	kN		Plastic collapse resistance in bending
R/R_0	1.00		(Figure 3-11)	With c = 0.00
R	438	kN		Plastic collapse resistance
$E_{allowable}$	352.49	kNm		Max absorbed energy
UC	**0.49**	**< 1.00**		**Unity Check = $E_{required}$ / $E_{allowable}$**
		Check ok		
Shear Check				
V	320	kN		Dynamic shear reaction
UC	**0.42**	**< 1.00**		**Unity Check = V / (0.60*1.20*f_y*A_w*C_v)**
		Check ok		

Calculation repeated for medium container

DROPPED OBJECT CHECK - DNV-RP-C204 Ed. Sept 2019, amended Sept 2021

VARIABLE	VALUE	UNIT	DNV REFERENCE	DESCRIPTION
Material Properties				
E	205000	MPa		Young modulus
f_y	355	MPa		Yield strength
Beam Properties				
Profile	HE340A			Section
Symmetry	Y			Y = symmetrical profile, S = stiffened, N = unsymmetrical profile
h	330	mm		Beam overall height (buckling check only)
h_w	243	mm		Web height (buckling check only)
b_f	300	mm		Flange width (buckling check only)
t_w	9.5	mm		Web thickness (buckling check only)
t_f	16.5	mm		Flange thickness (buckling check only)
t_{plate}	10	mm		Plate thickness (buckling check only)
$t_f + t_{plate}$	26.5	mm		Flange + Plate thickness (buckling check only)
r	27	mm		Radius
A	133.5	cm^2		Cross section area
A_w	29.83	cm^2		Section shear area
$W_{el,y}$	1678	cm^3		Elastic section modulus
$W_{pl,y}$	1850	cm^3		Plastic section modulus
M_p	657	kNm		Plastic bending moment
Beam Information				
L	6000	mm		Beam span
Type	1			Cross sectional type (DNV-OS-C101)
C_v	1.0			Shear coefficient
c_1	1.0			Restrain factor (2 = clamped ends, 1 = pinned ends)
w_c	166	mm		Characteristic deformation for plating
d_c	330	mm		Characteristic dimension for local buckling
Dropped Object Energy (DNV Sect. 4.3)				
W	5	t		Weight
	49.05	kN		
s	5	m		Travelled distance from drop point
g	9.81	m/s^2		
n	2			Number of impacted beams
v	9.90	m/s	(4.3)	Velocity for impacts in air
E_{kin}	245.25	kNm	(4.1)	Kinetic energy for objects falling in air (total)
E	122.625	kNm		Impact energy on each beam
Stiffeners Factors				
k_{beam}	9.12E+05	kN/m		Beam axial stiffness
k_{node}	1.00E+00	kN/m		Node axial stiffness (the considered member assumed removed)
1/k	1.00E+00		(3.9)	
k	1.00E+00	kN/m		Equivalent axial stiffness
c	3.89E-06			Non-dimensional spring stiffness
c_f	3.87E-06		(3.21)	Axial flexibility factor
kl	0.5			Smaller distance from location of collision load to adjacent joint (kl ≤ 0.5l)

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

Local Buckling - Max Deflection (DNV Sect. 3.10.2)				
β_{max}	1.17		(3.19)	Max slenderness ratio (buckling not to be considered if $\beta \leq \beta_{max}$)
Flange	1			Check considered (1 = yes, 0 = no)
β_f	34.79		(3.24/3.25)	Flange slenderness ratio
	β > βmax - Buckling required			
w_{bf}	805	mm	(3.22)	Max deflection - Flange buckling
Web	1			Check considered (1 = yes, 0 = no)
β_w	22.01		(3.26/3.27)	Web slenderness ratio
	β > βmax - Buckling required			
w_{bw}	3179	mm	(3.22)	Max deflection - Web buckling
Tensile fracture in yield hinges - Max deflection (DNV Sect. 3.10.4)				
ε_{cr}	0.15		(Table 3-3)	Critical strain for rupture
H	0.0034		(Table 3-3)	Non-dimensional plastic stiffness
ε_y	0.0017			Yield strain
c_{lp}	0.209		(3.30)	Plastic zone length factor
c_w	16.416		(3.29)	Displacement factor
w_f	813	mm	(3.28)	Max deflection - Tensile fracture
Energy Check				
w_{max}	805	mm		Max allowable beam deflection = min (w_{bf}, w_{bw}, w_f)
~~w~~	4.841			Non-dimensional deformation
R_0	438	kN		Plastic collapse resistance in bending
R/R_0	1.00		(Figure 3-11)	With c = 0.00
R	438	kN		Plastic collapse resistance
$E_{allowable}$	352.49	kNm		Max absorbed energy
UC	**0.35**	**< 1.00**		**Unity Check = $E_{required}$ / $E_{allowable}$**
	Check ok			
Shear Check				
V	316	kN		Dynamic shear reaction
UC	**0.41**	**< 1.00**		**Unity Check = V / (0.60*1.20*f_y*A_w*C_v)**
	Check ok			

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

10 SHIP IMPACT

The accelerations at Topside CoG due to ship impact are reported here below in Table 10.1 as per Design Basis, ref./20/.

Maximum and minimum accelerations at Topsides CoG resulting from ship impact scenario investigated for BLPH are lower than the In-service accelerations due to extreme hydrodynamic loads, see in-service analysis report, /25/ and therefore not governing the design.

Moreover, load combination factors for Accidental Limit State are lower than those for ULS. No further analysis for Ship impact case is needed.

Location	Elevation (LAT)	Min acceleration	Max acceleration	Min displacement	Max displacement
	[m]	[m/s^2]	[m/s^2]	[mm]	[mm]
Interface level	17.05	-2.3	3.0	-11	10
Topsides CoG	28.00	-1.1	1.2	-10	11

Table 10.1 - Topsides Accelerations and Displacements from Ship Impact

11 FIRE AND BLAST LOAD

The document ref./27/ reports that the risk is acceptable, section 6.1 stated that:

a) there are no areas in the platform in which the thermal radiation threshold contours of 37.5 kW/m2 from jet fire is equal to or above 1.0E-04 per year.

b) there are no areas in the platform in which the explosion threshold contours of 0.35, 0.27, 0.15 and 0.07 bar are equal to or above 1.0E-04 per year.

But as this is one of the first platforms of this type, it would also be important to do it right the first time and develop a standard for how to do this, hence:

a) **Fire load:** A fire load of 37.5 kW/m^2 adopted in the design is considered low for this type of platform. Therefore, several redundancy checks, based on critical element removal, will be performed. Jet fires are local and do not take out large sections of deck or truss.

b) **Blast load:** A distributed load of 0.07 bar acting downward on the deck over a distributed area load of 4x4 m^2 plate has been assessed.

11.1 JET FIRE LOAD

A redundancy check has been performed considering:

- Combined platform operating weight (excluding live load) = 2202 mt
- Elements deleted to simulate loss of node integrity

The primary structure is not protected by passive fire protection.

The amin fire risk comes from jet fires, nearly all hydrogen inventory is located above the upper deck. To verify the structure has sufficient redundancy to withstand a jet fire, additional checks are performed assuming certain typical nodes will have no more strength. A total of 6 cases have been identified:

1. Trunnion node A2 – all deck beams disconnected
2. Mid truss node A3 – node steel removed and vertical braces removed
3. Mid truss node 2B – node steel removed and vertical braces removed
4. Cantilever node C5 – node steel removed and vertical braces removed
5. Hydrogen storage vessel frame – one of the internal columns and attached support beam removed
6. Hydrogen storage vessel frame – one corner column and the external brace removed

11.1.1 Basic load cases and combinations

The model is based on the in-place SACS model and the operating load cases have been used, only the nominal center of gravity position has been included (no CoG shift considered).

Operating wind and accelerations (simulating waves actions) are included to proof that the structure can survive for a sufficient duration to allow for repairs to be done.

Below the load combination summary used in the analysis:

		LCOMB	G001	$HA5	$HA1	$HC5	$HC1	Q001	WOPA	WOPB	WOPC	WOPD	WOPE	WOPF	WOPG	WOPH	AOPA	AOPB	AOPC	AOPD	AOPE	AOPF	AOPG	AOPH	CRAR	CRAA	CRAB	CRAC	CRAD	CRAE	CRAF	CRAG	CRAH
COG NOMINAL POS	OPERATING	OAN1	1.00					1.00																	1.30								
		OANA	1.00					1.00	1.00								1.00									1.30								
		OANB	1.00					1.00		1.00								1.00									1.30							
		OANC	1.00					1.00			1.00								1.00									1.30						
		OAND	1.00					1.00				1.00								1.00										1.30				
		OANE	1.00					1.00					1.00								1.00											1.30		
		OANF	1.00					1.00						1.00								1.00										1.30		
		OANG	1.00					1.00							1.00								1.00										1.30	
		OANH	1.00					1.00								1.00								1.00										1.30

		LCOMB	G001	$HA5	$HA1	$HC5	$HC1	Q001	WEXA	WEXB	WEXC	WEXD	WEXE	WEXF	WEXG	WEXH	AEXA	AEXB	AEXC	AEXD	AEXE	AEXF	AEXG	AEXH	CRAR
	EXTREME	EANA	1.00					1.00	1.00								1.00								1.30
		EANB	1.00					1.00		1.00								1.00							1.30
		EANC	1.00					1.00			1.00								1.00						1.30
		EAND	1.00					1.00				1.00								1.00					1.30
		EANE	1.00					1.00					1.00								1.00				1.30
		EANF	1.00					1.00						1.00								1.00			1.30
		EANG	1.00					1.00							1.00								1.00		1.30
		EANH	1.00					1.00								1.00								1.00	1.30

Table 11.1 – Unfactored Load combinations from Ref. /25/

```
********** SACS IV SEASTATE PROGRAM **********              DATE 18-NOV-2024  TIME 09:21:33   SEA PAGE   132

          TECON - BLPH TOPSIDE & TRANSITION PIECE - IN-SERVICE ANALYSIS rev.1

                          ************* SEASTATE LOAD CASE CENTER REPORT *************
                                          RELATIVE TO STRUCTURAL ORIGIN
  222   OAN1        -0.00    306.38    255.20     -9.21       0.00     24.48    -92.06     13.38   -23605.27      0.33      0.46     27.93
  223   OANA      2193.02      0.66      0.13     27.93       0.00     24.48    -92.06     13.38   -23761.27      0.38      0.55     27.95
  224   OANB      1550.46      0.66      0.13     27.93    1373.35      0.49      0.02     27.69   -23761.27      0.38      0.55     27.95
  225   OANC        -0.00    306.38    255.20     -9.21    1981.50      0.64      0.29     27.76   -23761.27      0.38      0.55     27.95
  226   OAND    -1550.46      0.66      0.13     27.93    1373.35      0.49      0.02     27.69   -23761.27      0.38      0.55     27.95
  227   OANE    -2193.02      0.66      0.13     27.93       0.00     24.48    -92.06     13.38   -23761.27      0.38      0.55     27.95
  228   OANF    -1550.46      0.66      0.13     27.93   -1373.35      0.49      0.02     27.69   -23761.27      0.38      0.55     27.95
  229   OANG        -0.00    306.38    255.20     -9.21   -1942.50      0.49      0.02     27.69   -23761.27      0.38      0.55     27.95
  230   OANH     1550.46      0.66      0.13     27.93   -1373.35      0.49      0.02     27.69   -23761.27      0.38      0.55     27.95
```

Loadcase OAN1is the loadcase with all G and Q loads included.

```
  222   OAN1              1.0   * G001 + 1.0   * Q001 + 1.3   * CRAR

                  G001      100.00  1.1   * DEAZ + 1.0   * DEAC + 1.12  * WFLO + 1.12  * WPER +  +  +  +
                  Q001      100.00  1.12  * MECC + 1.0   * LILD + 1.0   * QSIL
                  CRAR      130.00  USER GENERATED LOADS
```

	FX (KN)	FY (KN)	FZ (KN)	MX (KN-M)	MY (KN-M)	MZ (KN-M)
G001	-0.000	0.000	-20982.654	433.008	1958.248	0.000
Q001	0.000	0.000	-2622.611	-11767.153	5938.209	0.000
CRAR	0.000	0.000	0.000	-156.000	0.000	0.000
TOTAL	-0.000	0.000	-23605.265	-11490.146	7896.457	0.000

For a more detailed description please refer to the in-service analysis report, Ref. /25/.

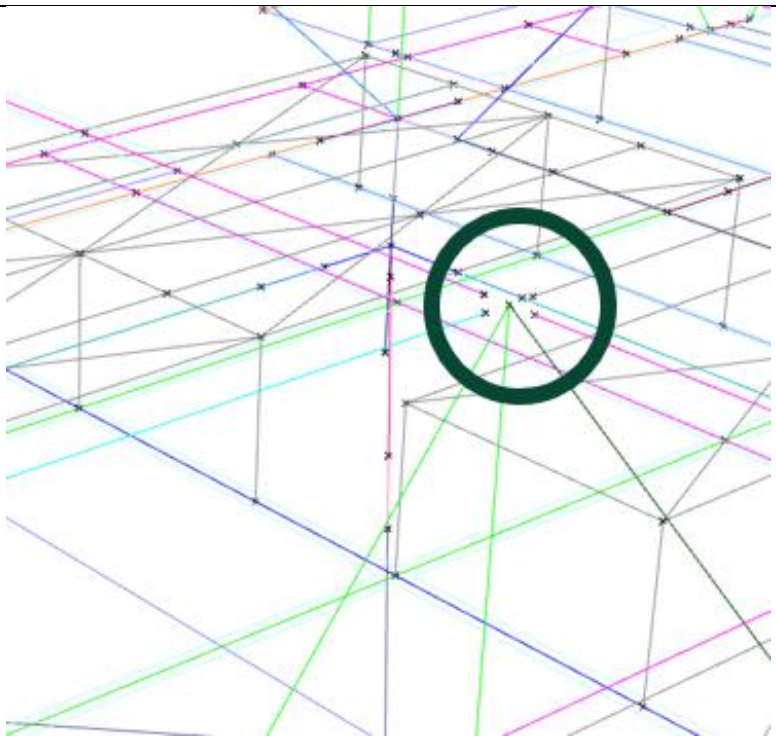
11.1.2 Results for the Static Checks

The code checks performed show that the structure can withstand the full failure of the typical nodes analysed.

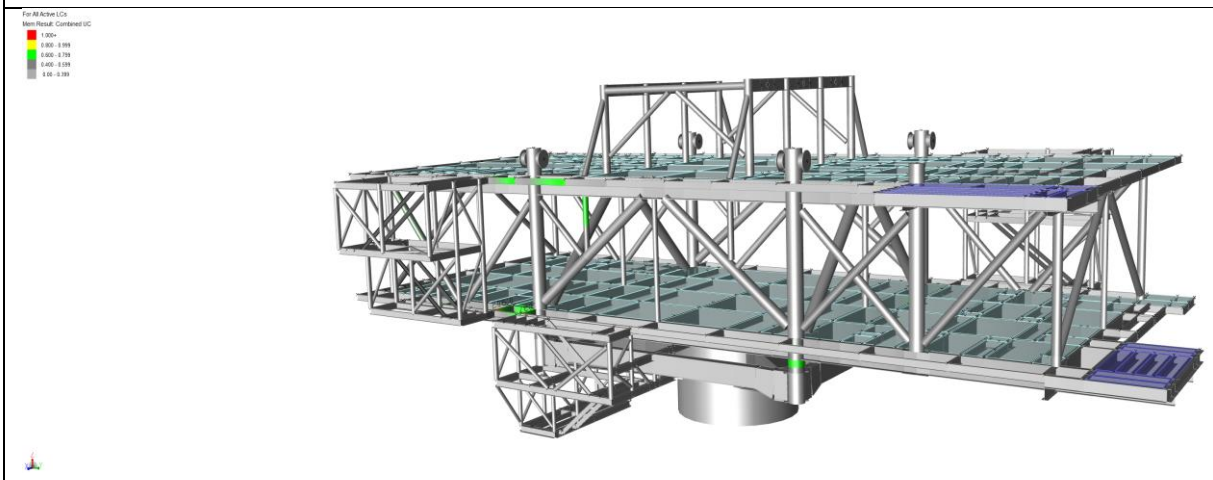
Case 1

Case 1 has the beams disconnected from trunnion node A2. The vertical braces are kept as they are connected to the tubular column and not the beam flange. The effective length of the column was doubled from 7m to 14m to simulate a full loss of lateral support at the upper deck level.

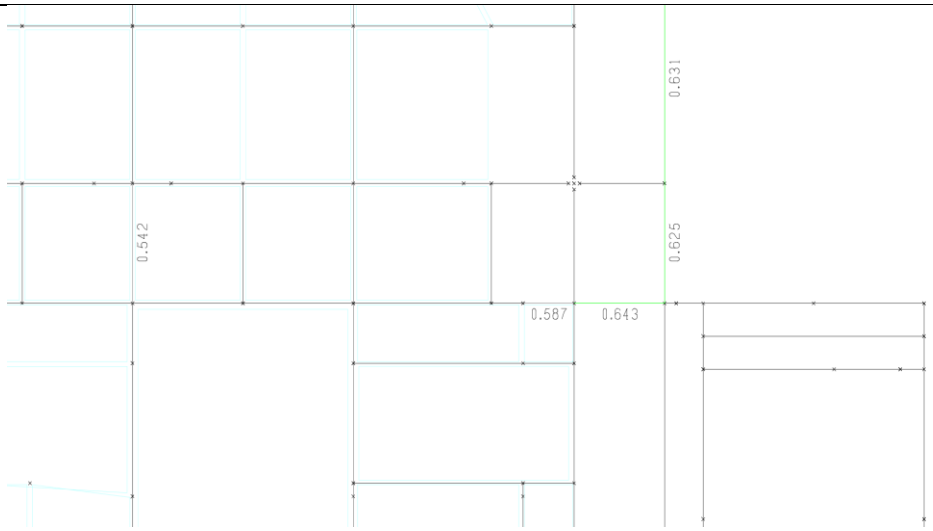
Case 1 Model plot



Overall UC plot



Upper deck unity check plot (local around disconnected node)



Unity check > 0.9

```
 TECON - BLPH TOPSIDE & TRANSITION PIECE - IN-SERVICE ANALYSIS rev.1          DATE 18-NOV-2024  TIME 09:21:38   PST PAGE  1650

                                        SACS-IV   MEMBER UNITY CHECK RANGE SUMMARY

                                     GROUP II  - UNITY CHECKS GREATER THAN    0.90 AND LESS THAN    1.10

                 MAXIMUM  LOAD  DIST   AXIAL   BENDING STRESS   SHEAR FORCE                      SECOND-HIGHEST  THIRD-HIGHEST
 MEMBER   GROUP COMBINED COND  FROM   STRESS     Y       Z       FY       FZ      KLY/RY  KLZ/RZ  UNITY    LOAD   UNITY    LOAD
           ID   UNITY CK  NO.  END    N/MM2    N/MM2   N/MM2    KN       KN                      CHECK    COND   CHECK    COND

L048-L065 S04     0.902  OANC   0.0    -2.18 -243.26  128.84  -44.51  210.33      30.5    22.0    0.897   OANB    0.883   OAND


                                        SACS-IV   MEMBER UNITY CHECK RANGE SUMMARY

                                     GROUP III - UNITY CHECKS GREATER THAN    1.10 AND LESS THAN  999.00

                                    ** NO UNITY CHECKS IN THIS GROUP **
```

Joint can unity checks > 0.25

TECON - BLPH TOPSIDE & TRANSITION PIECE - IN-SERVICE ANALYSIS rev.1 DATE 18-NOV-2024 TIME 09:21:58 JCN PAGE 36

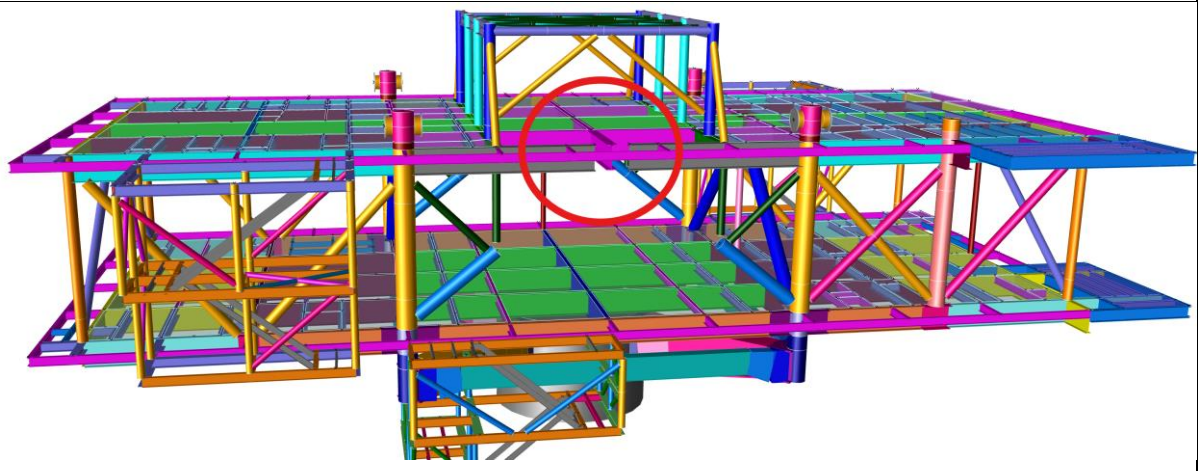
* * J O I N T C A N S U M M A R Y * *
(UNITY CHECK ORDER)

	ORIGINAL					LOAD DESIGN					STRENGTH ANALYSIS	
JOINT	DIAMETER (CM)	THICKNESS (CM)	YLD STRS (N/MM2)	LOAD UC	STRN UC	DIAMETER (CM)	THICKNESS (CM)	YLD STRS (N/MM2)	LOAD UC	STRN UC	BRACE JOINT	LOAD CASE
D005	55.000	2.000	400.000	0.644	0.644	55.000	2.000	400.000	0.644	0.644	U003	OANG
0002	40.640	2.062	355.000	0.348	0.348	40.640	2.062	355.000	0.348	0.348	L156	OANE
U003	80.000	3.000	400.000	0.315	0.315	80.000	3.000	400.000	0.315	0.315	D005	OANG
U015	80.000	3.000	400.000	0.300	0.300	80.000	3.000	400.000	0.300	0.300	L113	OANC
U045	70.000	3.000	400.000	0.290	0.290	70.000	3.000	400.000	0.290	0.290	0002	OANA
D006	55.000	2.000	400.000	0.284	0.284	55.000	2.000	400.000	0.284	0.284	U022	OANC
L156	70.000	3.000	400.000	0.278	0.278	70.000	3.000	400.000	0.278	0.278	U153	OANA
D004	55.000	2.000	400.000	0.278	0.278	55.000	2.000	400.000	0.278	0.278	U023	OANC
U005	80.000	3.000	400.000	0.262	0.262	80.000	3.000	400.000	0.262	0.262	L110	OANF
P102	45.720	1.905	355.000	0.256	0.256	45.720	1.905	355.000	0.256	0.256	U021	OANH

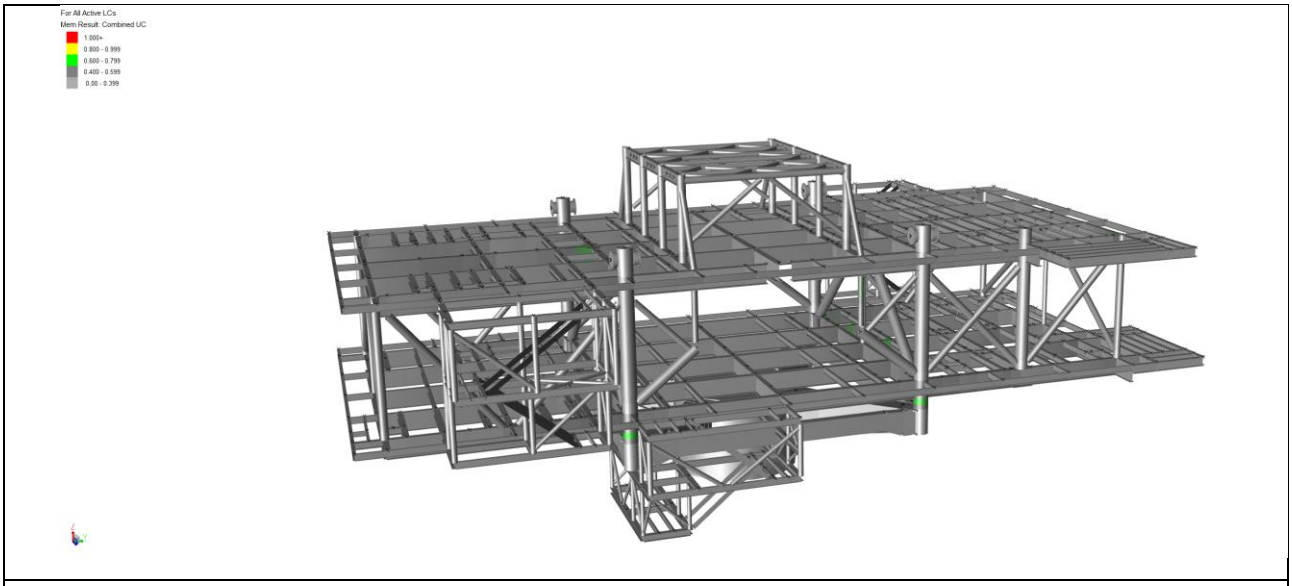
Case 2

Node 2B is removed, the braces welded to the bottom flange are taken out and all incoming deck beams are disconnected from the node.

Case 2 Model plot:



Overall UC plot



Unity check > 0.9

```
TECON - BLPH TOPSIDE & TRANSITION PIECE - IN-SERVICE ANALYSIS rev.1          DATE 18-NOV-2024  TIME 09:35:08   PST PAGE  1646

                                    SACS-IV   MEMBER UNITY CHECK RANGE SUMMARY

                                GROUP II  - UNITY CHECKS GREATER THAN    0.90 AND LESS THAN    1.10

                                  ** NO UNITY CHECKS IN THIS GROUP **


                                    SACS-IV   MEMBER UNITY CHECK RANGE SUMMARY

                                GROUP III - UNITY CHECKS GREATER THAN    1.10 AND LESS THAN  999.00

                                  ** NO UNITY CHECKS IN THIS GROUP **
```

Joint can unity checks > 0.25

```
TECON - BLPH TOPSIDE & TRANSITION PIECE - IN-SERVICE ANALYSIS rev.1          DATE 18-NOV-2024  TIME 09:35:17   JCN PAGE   36

                                        * * J O I N T   C A N   S U M M A R Y * *
                                                (UNITY CHECK ORDER)
        ***************** ORIGINAL ******************   ************ LOAD DESIGN ***********    *** STRENGTH ANALYSIS ****
                                          LOAD    STRN                                  LOAD    STRN    BRACE   LOAD
    JOINT DIAMETER THICKNESS  YLD STRS     UC      UC     DIAMETER THICKNESS  YLD STRS    UC      UC     JOINT   CASE
            (CM)       (CM)     (N/MM2)                      (CM)       (CM)     (N/MM2)

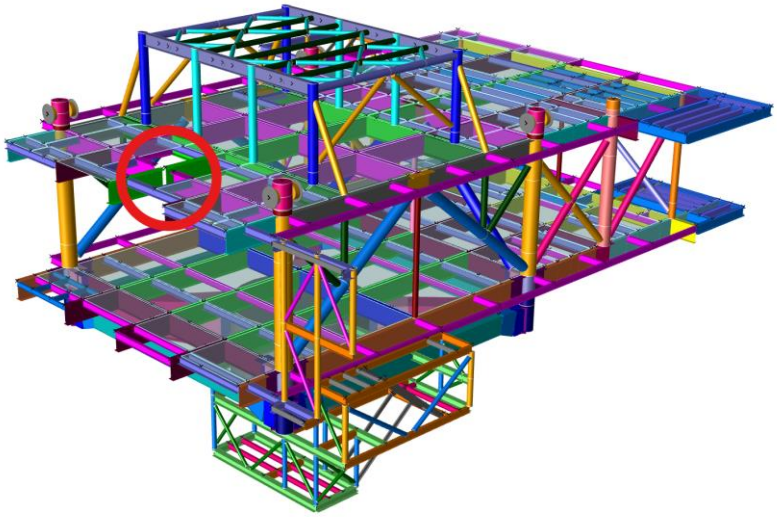
      D006  55.000     2.000    400.000   0.350   0.350     55.000     2.000    400.000   0.350   0.350   U022    STAT
      U015  80.000     3.000    400.000   0.310   0.310     80.000     3.000    400.000   0.310   0.310   L113    STAT
      U003  80.000     3.000    400.000   0.284   0.284     80.000     3.000    400.000   0.284   0.284   L033    STAT
      0002  40.640     2.062    355.000   0.271   0.271     40.640     2.062    355.000   0.271   0.271   L156    STAT
      L156  70.000     3.000    400.000   0.251   0.251     70.000     3.000    400.000   0.251   0.251   U153    STAT
      U045  70.000     3.000    400.000   0.250   0.250     70.000     3.000    400.000   0.250   0.250   0002    OANF
      D004  55.000     2.000    400.000   0.249   0.249     55.000     2.000    400.000   0.249   0.249   U023    OANC
```

Case 3

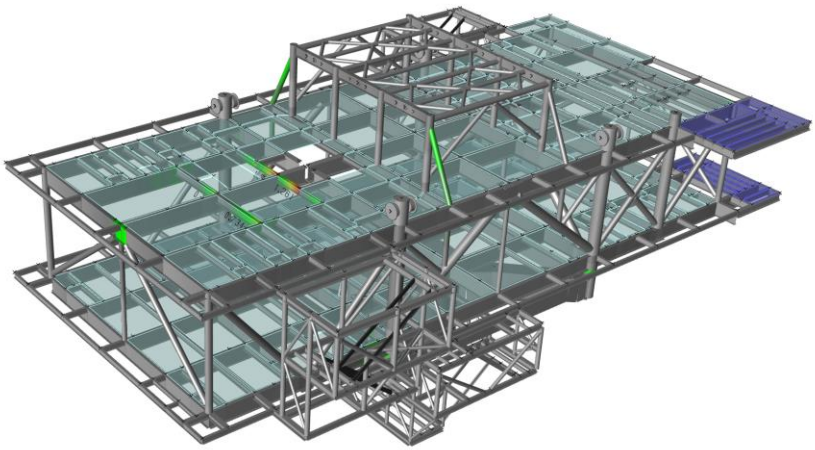
Node A3 is removed, the braces welded to the bottom flange are taken out and all incoming deck beams are disconnected from the node.

Case 3 shows some minor overstresses in this linear static check; this is considered acceptable as the central plate girder will be held in position by more than the two beams included in the main analysis model. The central plate girder will be held up by more secondary steel elements.

Case 3 Model plot:



Overall UC plot:



Unity check > 0.9

TECON - BLPH TOPSIDE & TRANSITION PIECE - IN-SERVICE ANALYSIS rev.1 DATE 18-NOV-2024 TIME 11:04:52 PST PAGE 1645

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP II - UNITY CHECKS GREATER THAN 0.90 AND LESS THAN 1.10

** NO UNITY CHECKS IN THIS GROUP **

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP III - UNITY CHECKS GREATER THAN 1.10 AND LESS THAN 999.00

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
U233-U239	S04	1.261	STAT	0.0	17.76	385.18	84.56	-40.39	-236.75	27.8	26.8	1.244	OANB	1.236	OANC
U237-U233	S04	1.242	STAT	2.0	16.22	386.75	75.14	34.43	236.35	27.8	26.8	1.229	OANB	1.224	OANC

Joint can unity checks > 0.25

TECON - BLPH TOPSIDE & TRANSITION PIECE - IN-SERVICE ANALYSIS rev.1 DATE 18-NOV-2024 TIME 11:05:09 JCN PAGE 36

* * J O I N T C A N S U M M A R Y * *
(UNITY CHECK ORDER)

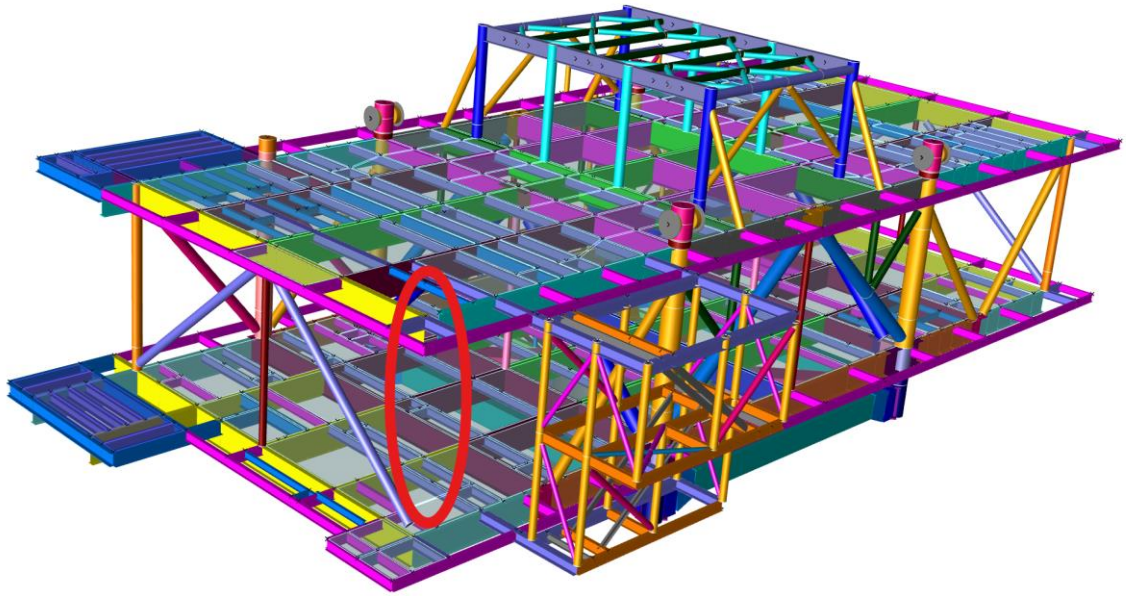
	ORIGINAL					LOAD DESIGN					STRENGTH ANALYSIS		
JOINT	DIAMETER (CM)	THICKNESS (CM)	YLD STRS (N/MM2)	LOAD UC	STRN UC	DIAMETER (CM)	THICKNESS (CM)	YLD STRS (N/MM2)	LOAD UC	STRN UC	BRACE JOINT	LOAD CASE
D003	55.000	2.000	400.000	0.493	0.493	55.000	2.000	400.000	0.493	0.493	U005	OANF
D005	55.000	2.000	400.000	0.430	0.430	55.000	2.000	400.000	0.430	0.430	U003	OANH
U003	80.000	3.000	400.000	0.394	0.394	80.000	3.000	400.000	0.394	0.394	L033	STAT
P101	45.720	1.905	355.000	0.359	0.359	45.720	1.905	355.000	0.359	0.359	U040	OANF
U005	80.000	3.000	400.000	0.354	0.354	80.000	3.000	400.000	0.354	0.354	L110	OANE
P102	45.720	1.905	355.000	0.351	0.351	45.720	1.905	355.000	0.351	0.351	U021	OANH
0002	40.640	2.062	355.000	0.316	0.316	40.640	2.062	355.000	0.316	0.316	L156	STAT
U015	80.000	3.000	400.000	0.289	0.289	80.000	3.000	400.000	0.289	0.289	L113	STAT
L156	70.000	3.000	400.000	0.272	0.272	70.000	3.000	400.000	0.272	0.272	U153	STAT
U045	70.000	3.000	400.000	0.245	0.245	70.000	3.000	400.000	0.245	0.245	0002	OANF

Case 4

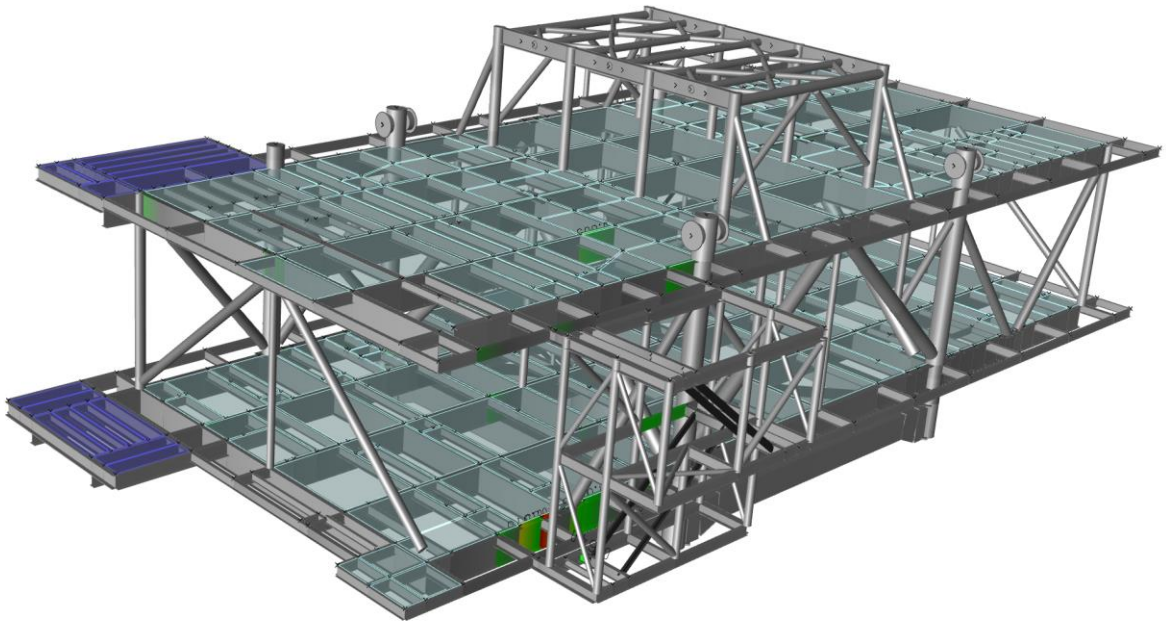
Cantilever node C5 is removed, the braces welded to the bottom flange are taken out and all incoming deck beams are disconnected from the node. The similar node on the crane side of the platform wasn't selected as the truss is more redundant with the x-bracing and additional column in the main truss.

One unity check of more than 1 is reported for case 4, but it is considered acceptable based on the fact it is an elastic check.

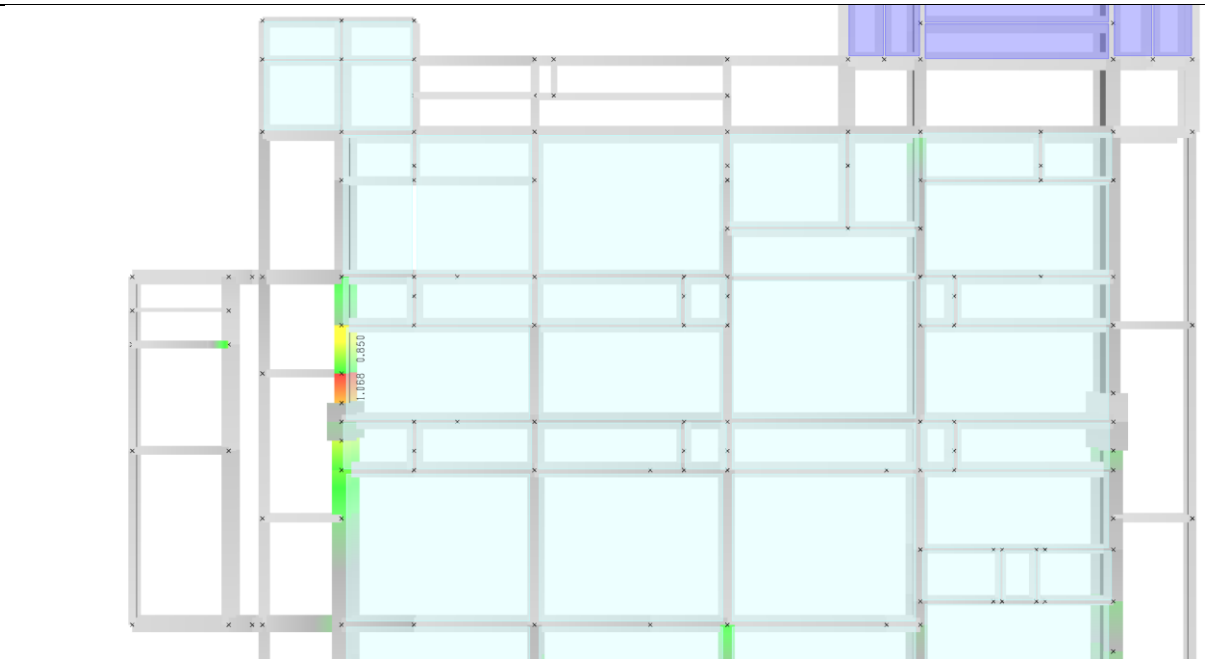
Case 4 Model plot:



Overall UC plot



Lower deck UC plot zoom



Unity check > 0.9

```
SACS CONNECT Edition V(16.0) - CL                                   Company: Shell Nederland B.V.
TECON - BLPH TOPSIDE & TRANSITION PIECE - IN-SERVICE ANALYSIS rev.1      DATE 18-NOV-2024  TIME 15:13:49   PST PAGE  1646

                                    SACS-IV   MEMBER UNITY CHECK RANGE SUMMARY

                                  GROUP II  - UNITY CHECKS GREATER THAN    0.90 AND LESS THAN    1.10

                  MAXIMUM  LOAD  DIST   AXIAL   BENDING STRESS   SHEAR FORCE                          SECOND-HIGHEST  THIRD-HIGHEST
 MEMBER   GROUP COMBINED COND  FROM   STRESS     Y       Z       FY       FZ      KLY/RY  KLZ/RZ  UNITY    LOAD   UNITY    LOAD
           ID   UNITY CK  NO.  END     N/MM2   N/MM2   N/MM2    KN       KN                      CHECK    COND   CHECK    COND

L154-L219 B05     1.068  OANE   0.0   -13.18 -181.03  -44.58   28.49  491.76      15.7   104.0    1.064    OANC    1.064    OAND


                                    SACS-IV   MEMBER UNITY CHECK RANGE SUMMARY

                                  GROUP III - UNITY CHECKS GREATER THAN    1.10 AND LESS THAN  999.00

                                ** NO UNITY CHECKS IN THIS GROUP **
```

Joint can unity checks > 0.25

```
TECON - BLPH TOPSIDE & TRANSITION PIECE - IN-SERVICE ANALYSIS rev.1      DATE 18-NOV-2024  TIME 15:03:55   JCN PAGE    35

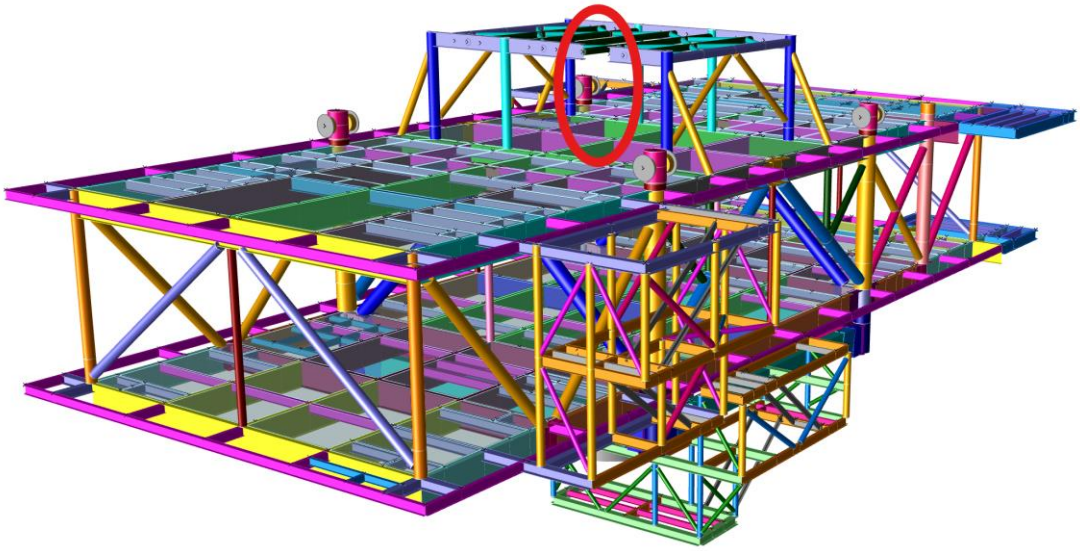
                                        * * J O I N T   C A N   S U M M A R Y * *
                                                (UNITY CHECK ORDER)
      ***************** ORIGINAL ******************    ************ LOAD DESIGN ***********    *** STRENGTH ANALYSIS ****
                                          LOAD    STRN                                  LOAD    STRN    BRACE   LOAD
JOINT DIAMETER THICKNESS  YLD STRS         UC      UC     DIAMETER THICKNESS  YLD STRS    UC      UC     JOINT   CASE
        (CM)      (CM)      (N/MM2)                         (CM)       (CM)     (N/MM2)

 0002  40.640    2.062    355.000    0.390   0.390     40.640    2.062    355.000    0.390    0.390    L156    OANE
 U045  70.000    3.000    400.000    0.313   0.313     70.000    3.000    400.000    0.313    0.313    0002    OANA
 L156  70.000    3.000    400.000    0.309   0.309     70.000    3.000    400.000    0.309    0.309    U153    OANA
 U015  80.000    3.000    400.000    0.308   0.308     80.000    3.000    400.000    0.308    0.308    L113    OANC
 U003  80.000    3.000    400.000    0.304   0.304     80.000    3.000    400.000    0.304    0.304    L033    OANH
 D006  55.000    2.000    400.000    0.276   0.276     55.000    2.000    400.000    0.276    0.276    U022    OANC
 U013  80.000    3.000    400.000    0.269   0.269     80.000    3.000    400.000    0.269    0.269    0002    OANB
 L013  80.000    4.000    400.000    0.257   0.257     80.000    4.000    400.000    0.257    0.257    0002    OANA
```

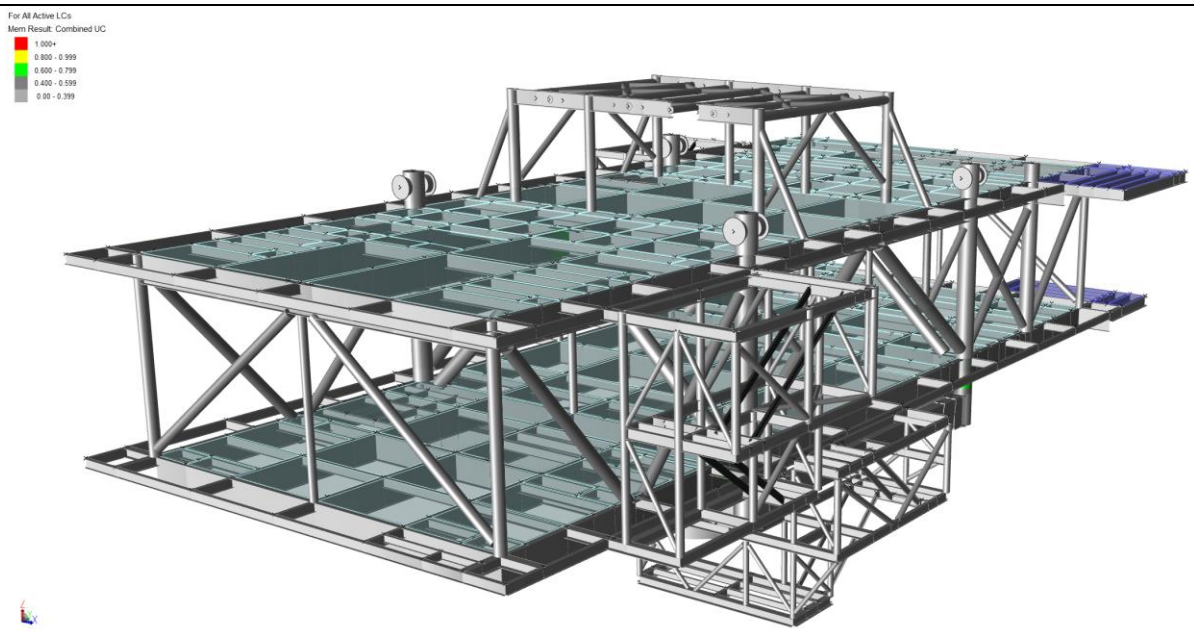
Case 5

One of the internal columns of the hydrogen vessel support frame (PAU) is removed and the beam discontinued.

Case 5 Model plot:



Overall UC plot



Unity check > 0.9

```
TECON - BLPH TOPSIDE & TRANSITION PIECE - IN-SERVICE ANALYSIS rev.1          DATE 18-NOV-2024  TIME 15:22:57   PST PAGE  1647

                                        SACS-IV   MEMBER UNITY CHECK RANGE SUMMARY

                                    GROUP II  - UNITY CHECKS GREATER THAN    0.90 AND LESS THAN    1.10

                                       ** NO UNITY CHECKS IN THIS GROUP **


                                    GROUP III - UNITY CHECKS GREATER THAN    1.10 AND LESS THAN  999.00

                                       ** NO UNITY CHECKS IN THIS GROUP **
```

Joint can unity checks > 0.25

```
TECON - BLPH TOPSIDE & TRANSITION PIECE - IN-SERVICE ANALYSIS rev.1          DATE 18-NOV-2024  TIME 15:23:08   JCN PAGE    35

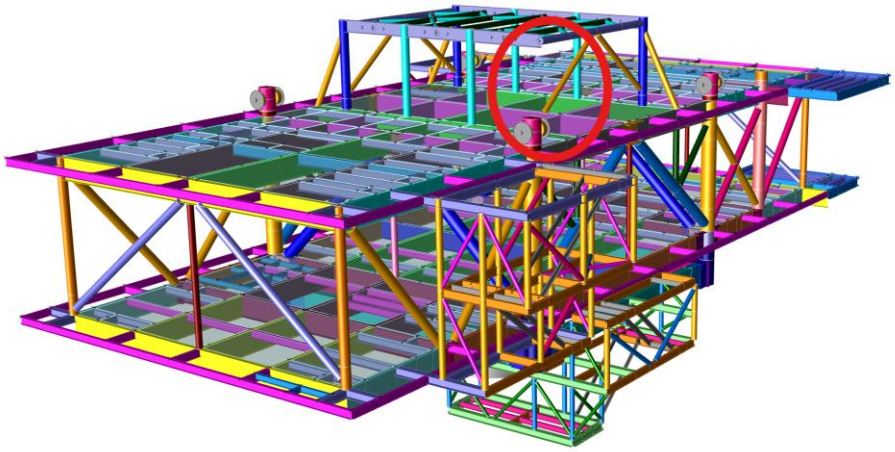
                                        * * J O I N T   C A N   S U M M A R Y * *
                                                (UNITY CHECK ORDER)
      ***************** ORIGINAL ******************   ************ LOAD DESIGN ***********   *** STRENGTH ANALYSIS ****
                                          LOAD    STRN                                  LOAD    STRN    BRACE   LOAD
JOINT DIAMETER THICKNESS   YLD STRS       UC      UC     DIAMETER THICKNESS  YLD STRS    UC      UC      JOINT   CASE
        (CM)      (CM)      (N/MM2)                         (CM)      (CM)     (N/MM2)

 0002  40.640    2.062    355.000    0.351   0.351     40.640    2.062    355.000    0.351   0.351   L156    OANE
 U015  80.000    3.000    400.000    0.296   0.296     80.000    3.000    400.000    0.296   0.296   L113    OANC
 U003  80.000    3.000    400.000    0.295   0.295     80.000    3.000    400.000    0.295   0.295   L033    OANH
 U045  70.000    3.000    400.000    0.291   0.291     70.000    3.000    400.000    0.291   0.291   0002    OANA
 D006  55.000    2.000    400.000    0.288   0.288     55.000    2.000    400.000    0.288   0.288   U022    OANC
 L156  70.000    3.000    400.000    0.281   0.281     70.000    3.000    400.000    0.281   0.281   U153    OANA
 D004  55.000    2.000    400.000    0.274   0.274     55.000    2.000    400.000    0.274   0.274   U023    OANC
 P139  27.310    1.588    355.000    0.259   0.259     27.310    1.588    355.000    0.259   0.259   P148    OANC
 U005  80.000    3.000    400.000    0.256   0.256     80.000    3.000    400.000    0.256   0.256   L110    OANF
 U013  80.000    3.000    400.000    0.249   0.249     80.000    3.000    400.000    0.249   0.249   0002    OANB
```

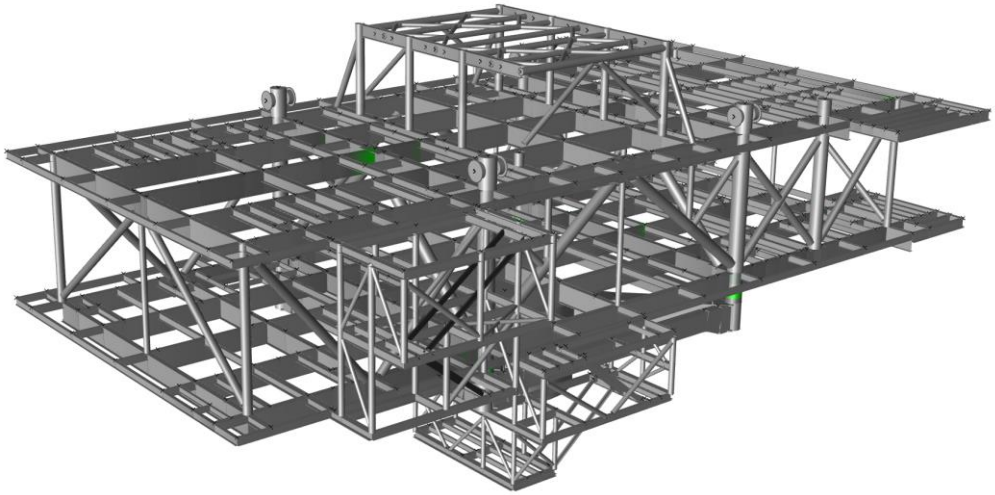
Case 6

One of the external columns of the hydrogen vessel support frame (PAU) is removed as well as the lateral brace.

Case 6 Model plot:



Overall UC plot



Unity check > 0.9

```
 SACS CONNECT Edition V(16.0) - CL                                    Company: Shell Nederland B.V.
TECON - BLPH TOPSIDE & TRANSITION PIECE - IN-SERVICE ANALYSIS rev.1    DATE 18-NOV-2024  TIME 14:00:47   PST PAGE  1647

                                  SACS-IV   MEMBER UNITY CHECK RANGE SUMMARY

                              GROUP II  - UNITY CHECKS GREATER THAN    0.90 AND LESS THAN    1.10

                                 ** NO UNITY CHECKS IN THIS GROUP **


                                  SACS-IV   MEMBER UNITY CHECK RANGE SUMMARY

                              GROUP III - UNITY CHECKS GREATER THAN    1.10 AND LESS THAN  999.00

                                 ** NO UNITY CHECKS IN THIS GROUP **
```

Joint can unity checks > 0.25

TECON - BLPH TOPSIDE & TRANSITION PIECE - IN-SERVICE ANALYSIS rev.1 DATE 18-NOV-2024 TIME 14:01:06 JCN PAGE 35

* * J O I N T C A N S U M M A R Y * *
(UNITY CHECK ORDER)

	ORIGINAL					LOAD DESIGN					STRENGTH ANALYSIS		
JOINT	DIAMETER (CM)	THICKNESS (CM)	YLD STRS (N/MM2)	LOAD UC	STRN UC	DIAMETER (CM)	THICKNESS (CM)	YLD STRS (N/MM2)	LOAD UC	STRN UC	BRACE JOINT	LOAD CASE
0002	40.640	2.062	355.000	0.349	0.349	40.640	2.062	355.000	0.349	0.349	L156	OANE
D006	55.000	2.000	400.000	0.317	0.317	55.000	2.000	400.000	0.317	0.317	U022	OANC
U003	80.000	3.000	400.000	0.299	0.299	80.000	3.000	400.000	0.299	0.299	L033	OANH
U015	80.000	3.000	400.000	0.296	0.296	80.000	3.000	400.000	0.296	0.296	L113	OANC
U045	70.000	3.000	400.000	0.293	0.293	70.000	3.000	400.000	0.293	0.293	0002	OANA
L156	70.000	3.000	400.000	0.282	0.282	70.000	3.000	400.000	0.282	0.282	U153	OANA
D004	55.000	2.000	400.000	0.269	0.269	55.000	2.000	400.000	0.269	0.269	U023	OANC
U005	80.000	3.000	400.000	0.256	0.256	80.000	3.000	400.000	0.256	0.256	L110	OANF
P103	45.720	1.905	355.000	0.253	0.253	45.720	1.905	355.000	0.253	0.253	U022	OANB
U013	80.000	3.000	400.000	0.247	0.247	80.000	3.000	400.000	0.247	0.247	0002	OANB

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

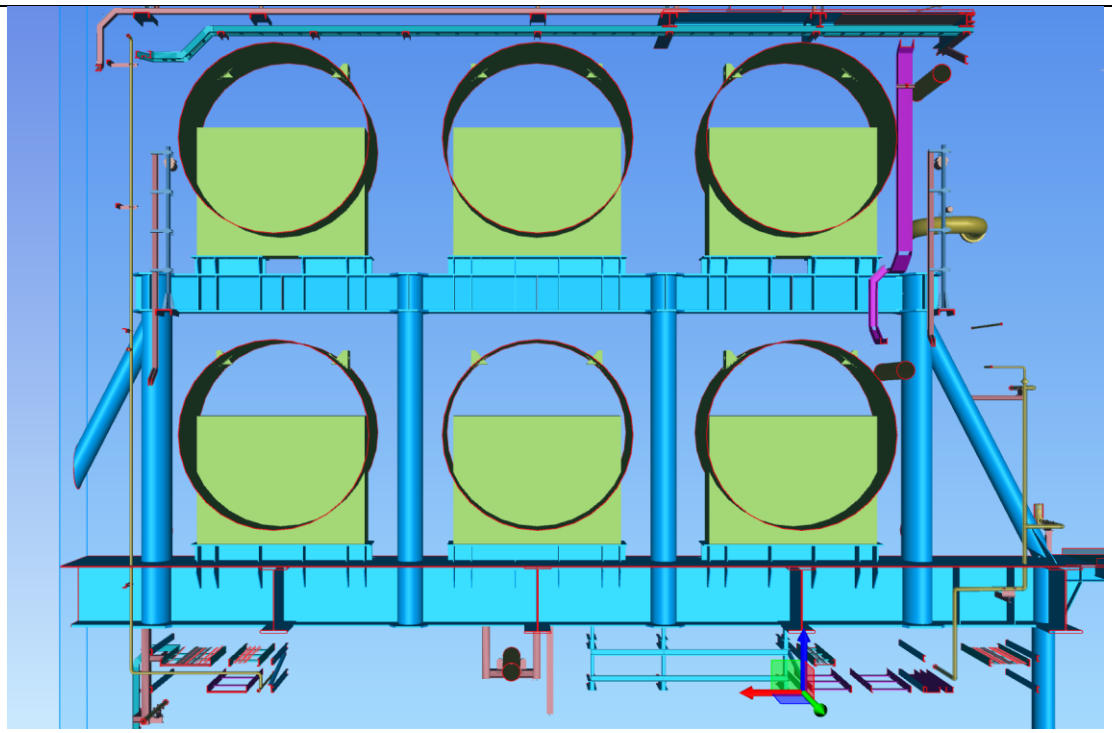
11.1.3 Qualitative discussion on H2 vessel saddles

The redundancy cases 5 & 6 have shown that an entire column can be removed and the upper vessel structure stays intact. The case not checked is the full saddle / supporting beam removal. With a total saddle width of ~2.5m this necessary requires a large jet diameter or a long duration and is not considered very likely. Applying PFP to the top saddles / beams was considered, but considered to have a disproportionate cost compared to the benefits, as shown in the ALARP demonstration presented in Appendix A.

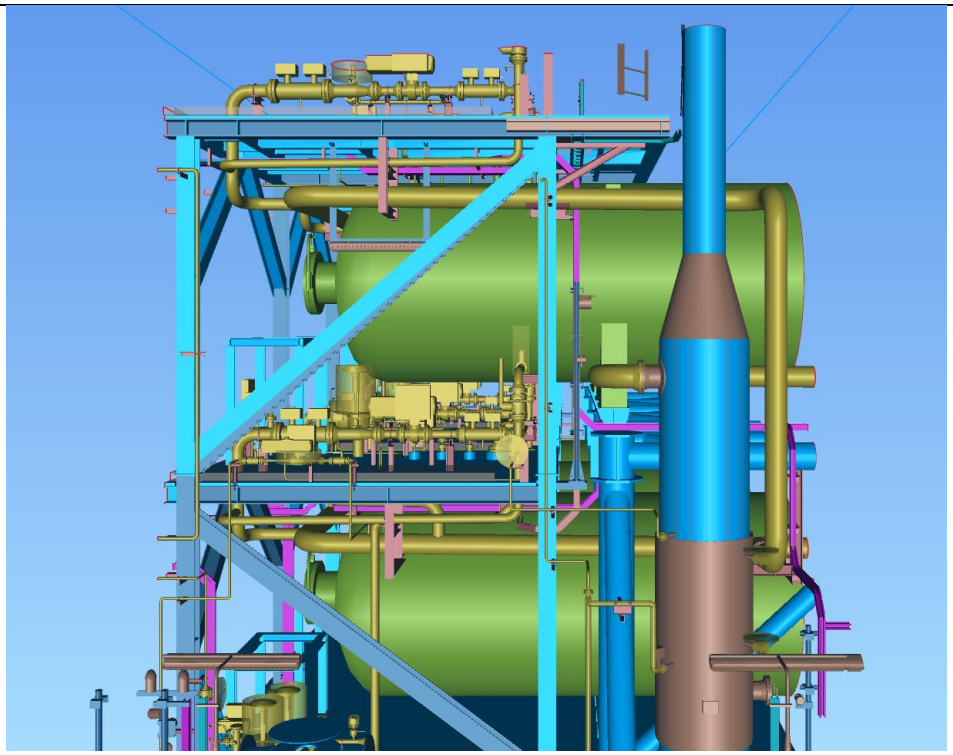
In addition, a consideration to would happen is presented below:

If a large jet fire fully encompasses a saddle the supporting beam and saddle will start to yield and deflect. The gap between support beam and lower vessel is approximately 500mm, once deflection reaches this the lower vessel will start to carry the weight, this occurs in the line where the saddle and lift points of the lower vessels are located and thus represent a strong point.

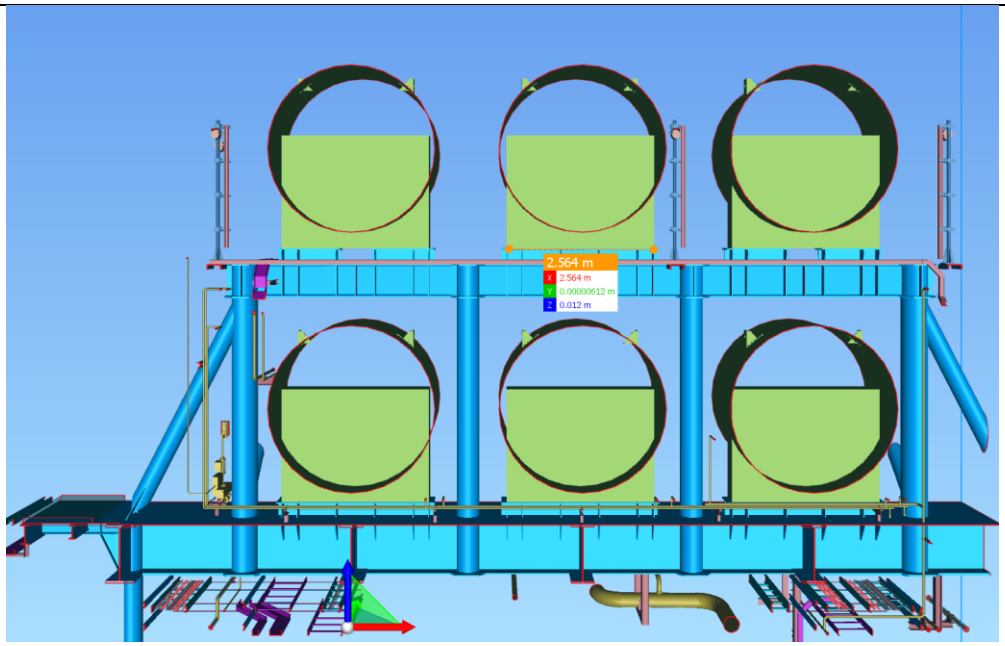
A flattening of the lower vessel could lead to the vessel ends touching the secondary vessel access platform, although half the weight of the vessel over the impact area exceeds design loads for the platform it does provide and combined with the support provided by the lower vessel it is considered unlikely



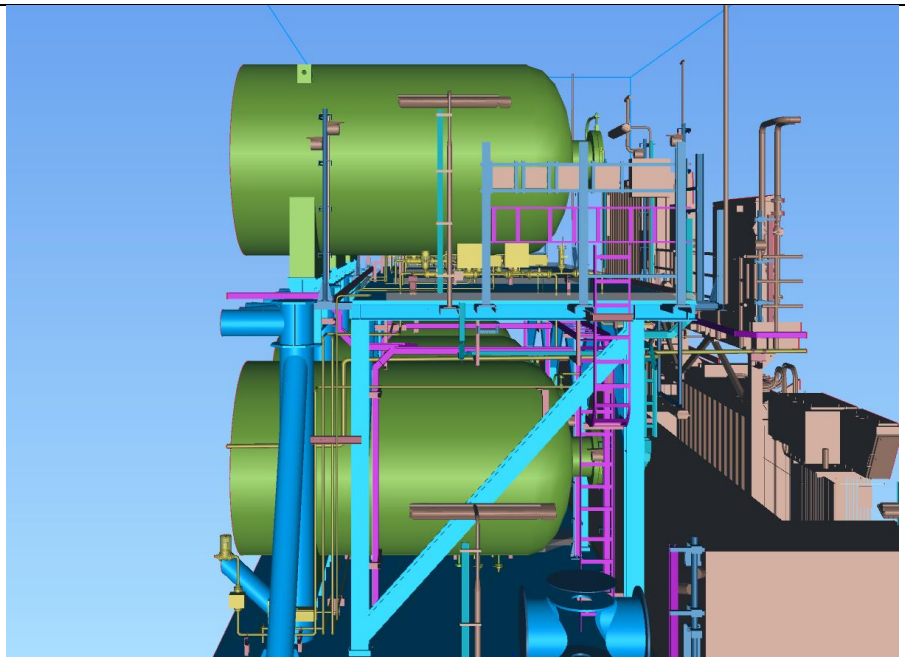
Cross section along saddles near row 4



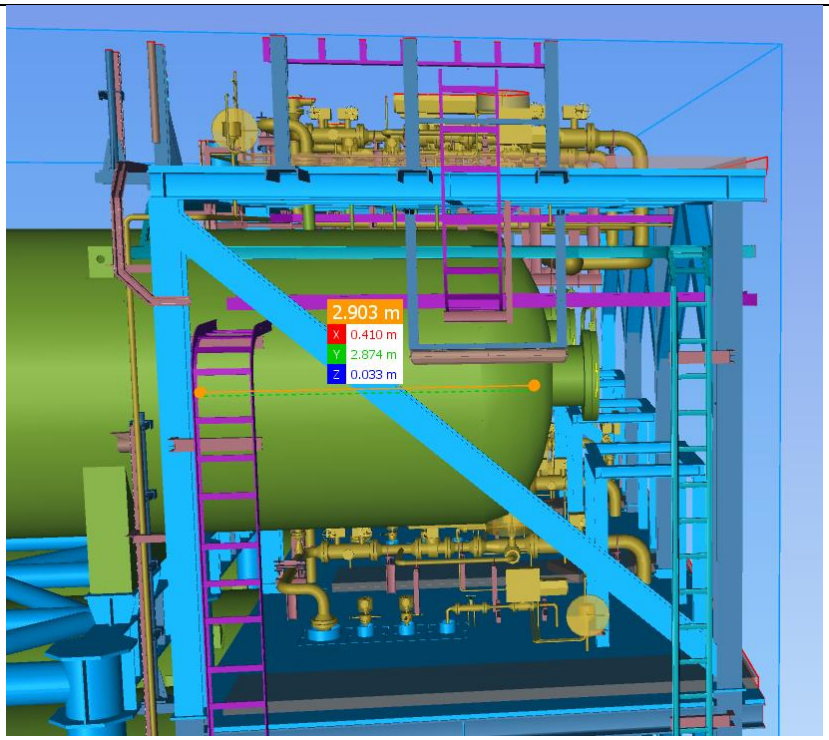
Cross section along saddles near row 4



Cross section along saddles near row 2



Cross section along saddles near row 2



Extent of vessel above platform

11.2 BLAST CHECK

Global check of the primary, secondary beams and plates has been performed adding to the global distributed load (permanent + live - see Table 11.1) an additional downward distributed load of 0.07 bar.

Area Use	Deck Flooring & Stringers	
	UDL (kN / m2)	CL (kN)
General Laydown and Storage Areas	15	22.5 (+10.0 for pipe support allowance)
Floor Areas in Deck	Actual equip. +5.0 in open areas or 15.0	22.5 (+10.0 for pipe support allowance)
Temporary Refuge	5	5
Walkways, Stairs and Access Platforms	4.5	4.5

Table 11.2 - Superimposed area loads for local checks

Deck beams are locally checked combining the dead weights with the distributed live loads. The checks are performed considering the beams simply supported at both ends.

11.2.1 Plan at elevation +30.310 – primary beams

The following figure shows the primary beams – and their properties – considered at elevation +30.310m.

The selected sections cover all the primary beams of the UD, as they are characterised by the smallest resistant section associated with the largest span.

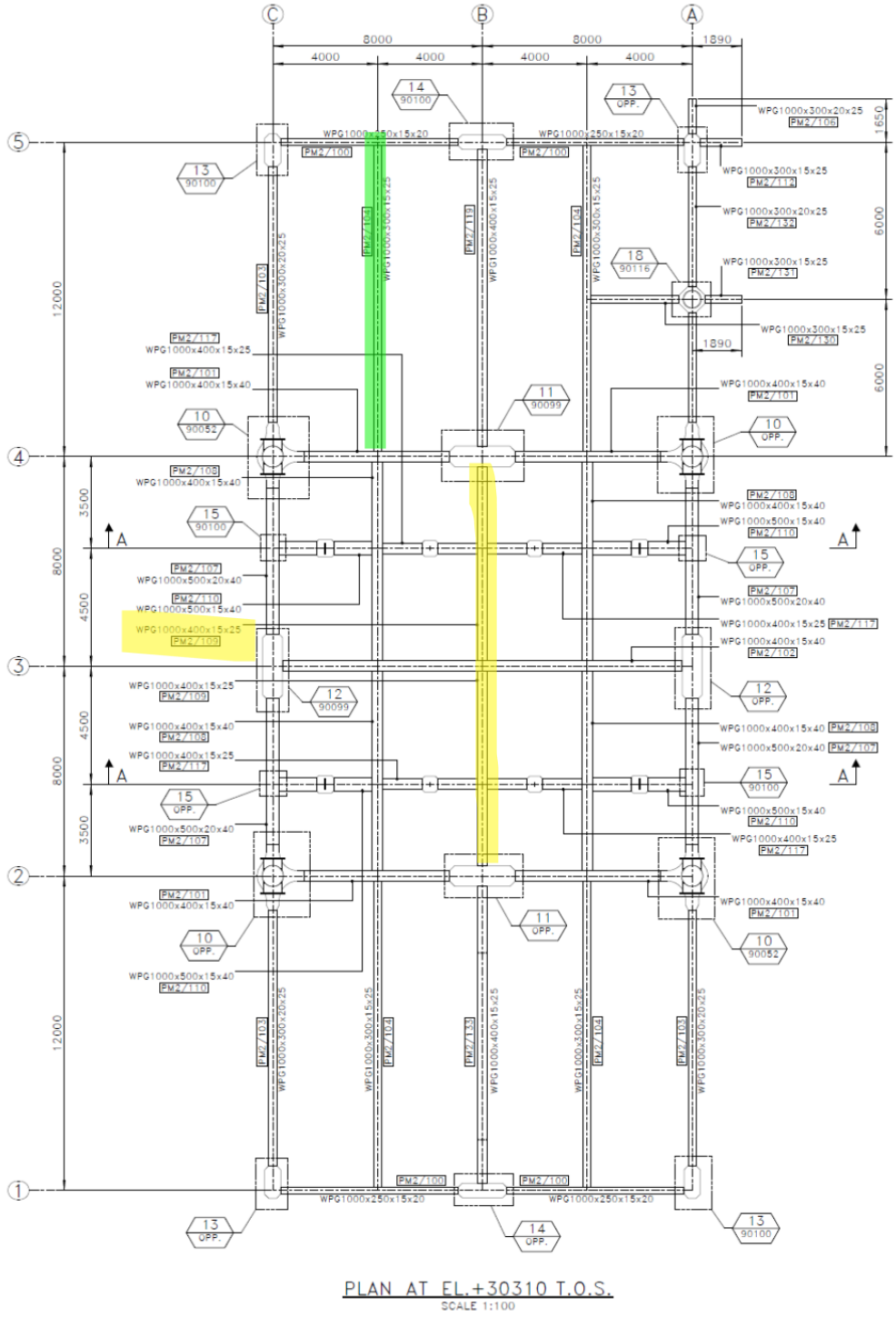


Figure 11.1 -Primary Beams checked at El. +30.310m - UD

BEAM CHECK UNDER DISTRIBUTED LOAD							
DESCRIPTION:	Level 2 - WPG1000x400x15x25					**- MAX UC = 0.99**	
DATA							
Shape:		WPG1000x400x15x25					
f_y =		345	MPa	Plate yield strength			
I =		5.826E+09	mm	Moment of inertia			
W_{el} =		1.17E+07	mm^3	Elastic section modulus			
W_{pl} =		1.31E+07	mm^3	Plastic section modulus			
A_v =		15000	mm^2	Shear area			
L =		16.000	m	Beam span			
b =		4.500	m	Beam spacing			
q_G =		2.50	kN/m^2	Permanent distributed load			
q_Q =		26.00	kN/m^2	Variable distributed load (15.0+7.0 blast)			
$\gamma_{f,G}$ =		1.00		Permanent load factor			
$\gamma_{f,Q}$ =		1.00		Variable load factor			
$p_1 = (\gamma_{f,G}\, q_G + \gamma_{f,Q}\, q_Q)\, b$ =		128.3	kN/m	Total factored distributed load			
$p_2 = (q_G + q_Q)\, b$ =		128.3	kN/m	Total unfactored distributed load			
$p_Q = q_Q\, b$ =		117.0	kN/m	Variable unfactored distributed load			
γ_{M0} =		1.10		Strength resistance factor			
Restraint scheme		1		Support - Support			
BENDING CHECK							
M_{ed} =	1 / 8 $p_1 L^2$ =	4104.0	kNm	Design bending moment			
$M_{c,Rd} = W_{el}\, f_y / \gamma_{M0}$ =		4119.4	kNm	> M_{Ed} - UC =	1.00	- Bending check	
SHEAR CHECK							
V_{ed} =	1 / 2 $p_1 L$ =	1026	kN	Design shear force			
$V_{c,Rd} = A_v\, (f_y / \sqrt{3}) / \gamma_{M0}$ =		2716	kN	> VEd - UC =	0.38	- Shear check	

Table 11.3 – PG 1000x400x15x25 – L=16m

BEAM CHECK UNDER DISTRIBUTED LOAD							
DESCRIPTION:	Level 2 - WPG1000x300x15x25					**- MAX UC = 0.52**	
DATA							
Shape:		Level 1 - WPG1000x300x15x25					
f_y =		345	MPa	Plate yield strength			
I =		4.637E+09	mm	Moment of inertia			
W_{el} =		9.27E+06	mm^3	Elastic section modulus			
W_{pl} =		1.07E+07	mm^3	Plastic section modulus			
A_v =		15000	mm^2	Shear area			
L =		12.000	m	Beam span			
b =		4.000	m	Beam spacing			
q_G =		2.50	kN/m^2	Permanent distributed load			
q_Q =		22.00	kN/m^2	Variable distributed load (15.0+7.0 blast)			
$\gamma_{f,G}$ =		1.00		Permanent load factor			
$\gamma_{f,Q}$ =		1.00		Variable load factor			
$p_1 = (\gamma_{f,G}\, q_G + \gamma_{f,Q}\, q_Q)\, b$ =		98.0	kN/m	Total factored distributed load			
$p_2 = (q_G + q_Q)\, b$ =		98.0	kN/m	Total unfactored distributed load			
$p_Q = q_Q\, b$ =		88.0	kN/m	Variable unfactored distributed load			
γ_{M0} =		1.10		Strength resistance factor			
Restraint scheme		1		Support - Support			
BENDING CHECK							
M_{ed} =	1 / 8 $p_1 L^2$ =	1764.0	kNm	Design bending moment			
$M_{c,Rd} = W_{el}\, f_y / \gamma_{M0}$ =		3354.9	kNm	> M_{Ed} - UC =	0.53	- Bending check	
SHEAR CHECK							
V_{ed} =	1 / 2 $p_1 L$ =	588	kN	Design shear force			
$V_{c,Rd} = A_v\, (f_y / \sqrt{3}) / \gamma_{M0}$ =		2716	kN	> VEd - UC =	0.22	- Shear check	

Table 11.4 – PG 1000x300x15x25 – L=12m

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

11.2.2 Plan at elevation +30.310 – secondary beams

The following figure shows the secondary beams – and their properties - considered at elevation +30.310m.

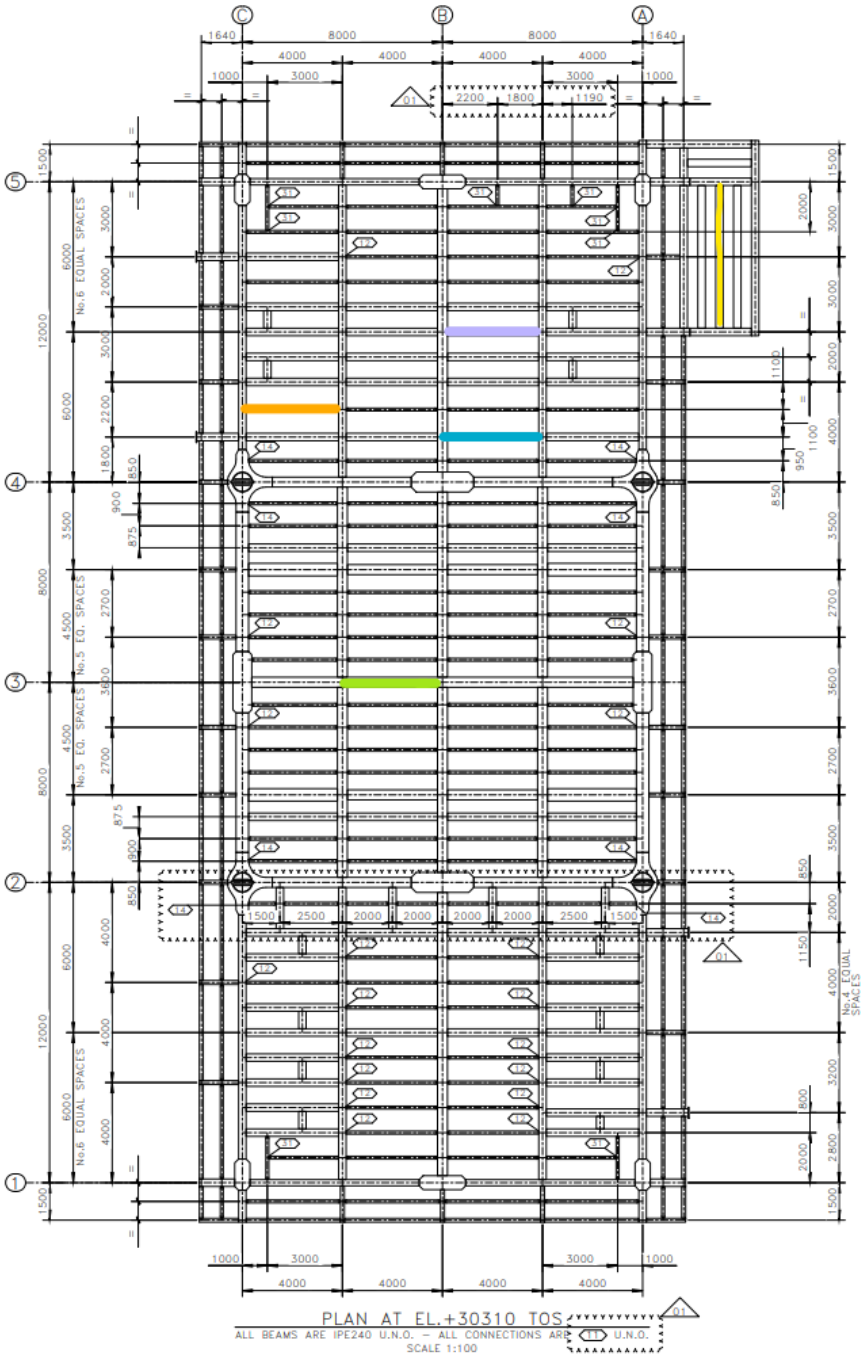


Figure 11.2 - Secondary beams checked at el. +30.31 m

Table 11.5 - IPE240 – A – 4000mm

BEAM CHECK UNDER DISTRIBUTED LOAD						
DESCRIPTION:	Utility Deck - IPE240 - A - L:4000					**- MAX UC = 0.5**
DATA						
Shape:		IPE240				
f_y =		355	MPa	Plate yield strength		
I =		3.892E+07	mm	Moment of inertia		
W_{el} =		3.243E+05	mm^3	Elastic section modulus		
A_v =		1914	mm^2	Shear area		
L =		4.000	m	Beam span		
b =		1.100	m	Beam spacing		
q_G =		2.00	kN/m^2	Permanent distributed load		
q_Q =		22.00	kN/m^2	Variable distributed load (15.0+7.0 blast)		
$\gamma_{f,G}$ =		1.00		Permanent load factor		
$\gamma_{f,Q}$ =		1.00		Variable load factor		
$p_1 = (\gamma_{f,G}\, q_G + \gamma_{f,Q}\, q_Q)\, b$ =		26.4	kN/m	Total factored distributed load		
$p_2 = (q_G + q_Q)\, b$ =		26.4	kN/m	Total unfactored distributed load		
$p_Q = q_Q\, b$ =		24.2	kN/m	Variable unfactored distributed load		
γ_{M0} =		1.10		Strength resistance factor		
Restraint scheme		1		Support - Support		
BENDING CHECK						
M_{ed} =	1 / 8 $p_1 L^2$ =	52.8	kNm	Design bending moment		
$M_{c,Rd} = W_{el} f_y / \gamma_{M0}$ =		104.7	kNm	> M_{Ed} - UC =	0.50	- Bending check
SHEAR CHECK						
V_{ed} =	1 / 2 $p_1 L$ =	53	kN	Design shear force		
$V_{c,Rd} = A_v (f_y/\sqrt{3}) / \gamma_{M0}$ =		357	kN	> VEd - UC =	0.15	- Shear check

Table 11.6 - IPE330 – B – 4000mm

BEAM CHECK UNDER DISTRIBUTED LOAD						
DESCRIPTION:	Utility Deck - IPE330 - C - L:4000					**- MAX UC = 0.2**
DATA						
Shape:		IPE330				
f_y =		355	MPa	Plate yield strength		
I =		1.177E+08	mm	Moment of inertia		
W_{el} =		7.131E+05	mm^3	Elastic section modulus		
A_v =		3081	mm^2	Shear area		
L =		4.000	m	Beam span		
b =		1.000	m	Beam spacing		
q_G =		2.00	kN/m^2	Permanent distributed load		
q_Q =		22.00	kN/m^2	Variable distributed load (15.0+7.0 blast)		
$\gamma_{f,G}$ =		1.00		Permanent load factor		
$\gamma_{f,Q}$ =		1.00		Variable load factor		
$p_1 = (\gamma_{f,G}\, q_G + \gamma_{f,Q}\, q_Q)\, b$ =		24.0	kN/m	Total factored distributed load		
$p_2 = (q_G + q_Q)\, b$ =		24.0	kN/m	Total unfactored distributed load		
$p_Q = q_Q\, b$ =		22.0	kN/m	Variable unfactored distributed load		
γ_{M0} =		1.10		Strength resistance factor		
Restraint scheme		1		Support - Support		
BENDING CHECK						
M_{ed} =	1 / 8 $p_1 L^2$ =	48.0	kNm	Design bending moment		
$M_{c,Rd} = W_{el} f_y / \gamma_{M0}$ =		230.2	kNm	> M_{Ed} - UC =	0.21	- Bending check
SHEAR CHECK						
V_{ed} =	1 / 2 $p_1 L$ =	48	kN	Design shear force		
$V_{c,Rd} = A_v (f_y/\sqrt{3}) / \gamma_{M0}$ =		574	kN	> VEd - UC =	0.08	- Shear check

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

11.2.3 Floor Plates

The checks are performed considering all the plates edges fixed and the span equal to the secondary beams spacing. This section shows the results for 8mm thick plate; these plates are used for floor areas, temporary refuge, walkways, stairs and access platforms.

Table 11.7 – 8mm thk PLATE

PLATE CHECK UNDER DISTRIBUTED LOAD							
DESCRIPTION:	Thk 8.0 mm						**- MAX UC = 0.67**
DATA							
f_y =			355	MPa	Plate yield strength		
t =			8	mm	Plate thickness		
b =			1100	mm	Plate span (beam spacing)		
B =			1000	mm	Nominal plate width		
I = B t^3 / 12 =			4.267E+04	mm^4	Moment of inertia		
Wel = B t^2 / 6 =			1.067E+04	mm^3	Elastic section modulus		
Av = B t =			8000	mm^2	Shear area		
q_G =			1.00	kN/m^2	Permanent distributed load		
q_Q =			22.00	kN/m^2	Variable distributed load		
$\gamma_{f,G}$ =			1.00		Permanent load factor		
$\gamma_{f,Q}$ =			1.00		Variable load factor		
$p_1 = (\gamma_{f,G}\, q_G + \gamma_{f,Q}\, q_Q)$ B =			23.0	kN/m	Total factored distributed load		
$p_2 = (q_G + q_Q)$ B =			23.0	kN/m	Total unfactored distributed load		
γ_{M0} =			1.10		Strength resistance factor		
Restraint scheme			3		Fixed - Fixed		
BENDING CHECK							
M_{ed} =	1 / 12	p_1 b^2 =	2.3	kNm	Design bending moment		
$M_{c,Rd} = W_{el} f_y / \gamma_{M0}$ =			3.4	kNm	> M_{Ed} - UC =	**0.67**	**- Bending check**
SHEAR CHECK							
V_{ed} =	1 / 2	p_1 b =	13	kN	Design shear force		
$V_{c,Rd} = A_v (f_y / \sqrt{3}) / \gamma_{M0}$ =			1491	kN	> V_{Ed} - UC =	**0.01**	**- Shear check**

11.3 BLAST CHECK - ADDITIONAL STRUCTURAL CHECK

In addition to the global blast on the entire deck a few local checks have been performed with a higher blast loads. The following basic load cases have been used for this.

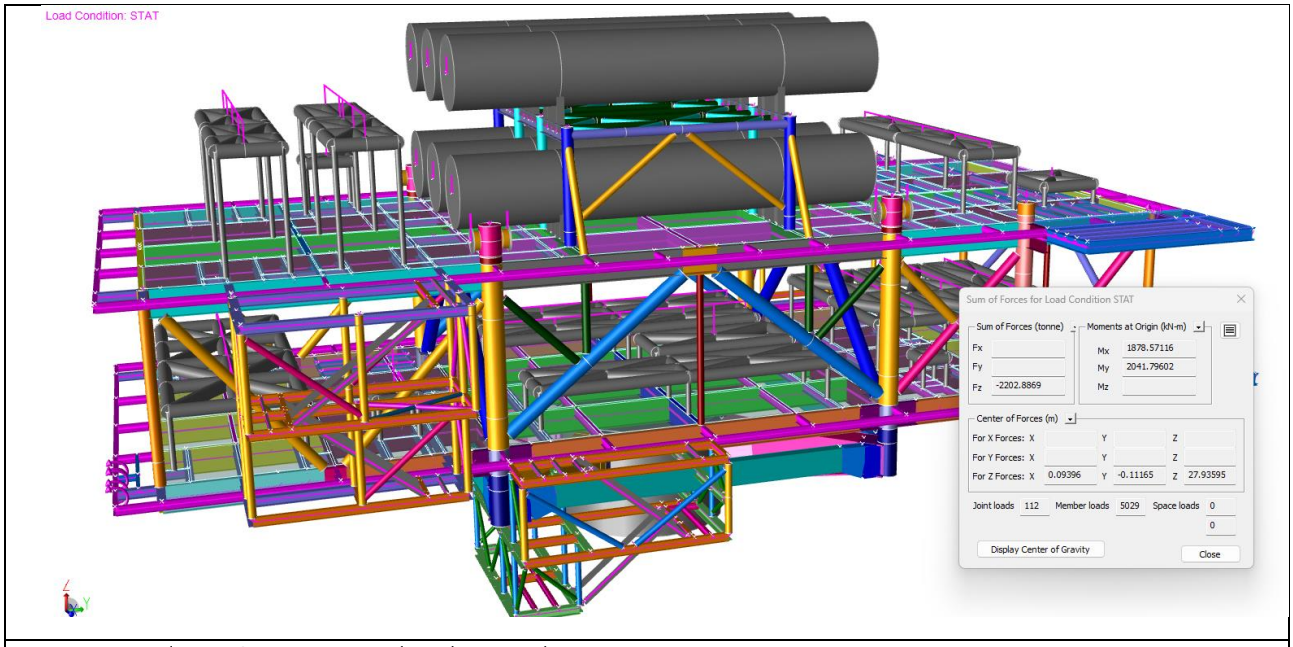
- 1.0 Bar overpressure on the upper deck on 3 positions
- 2.0 Bar overpressure on the upper deck on 3 positions
- 1.0 Bar on one of the lower hydrogen storage vessels
- 0.9 Bar on one of the lower hydrogen storage vessels

The structural checks are done statically and with all load and resistance factors set to 1.0. A dynamic simulation of one of the upper deck positions and the upper vessel has been done to determine the dynamic amplification factors. This has been done using a model with the monopile included and fixed at an elevation of 1.5xD below the mudline, see section 11.3.

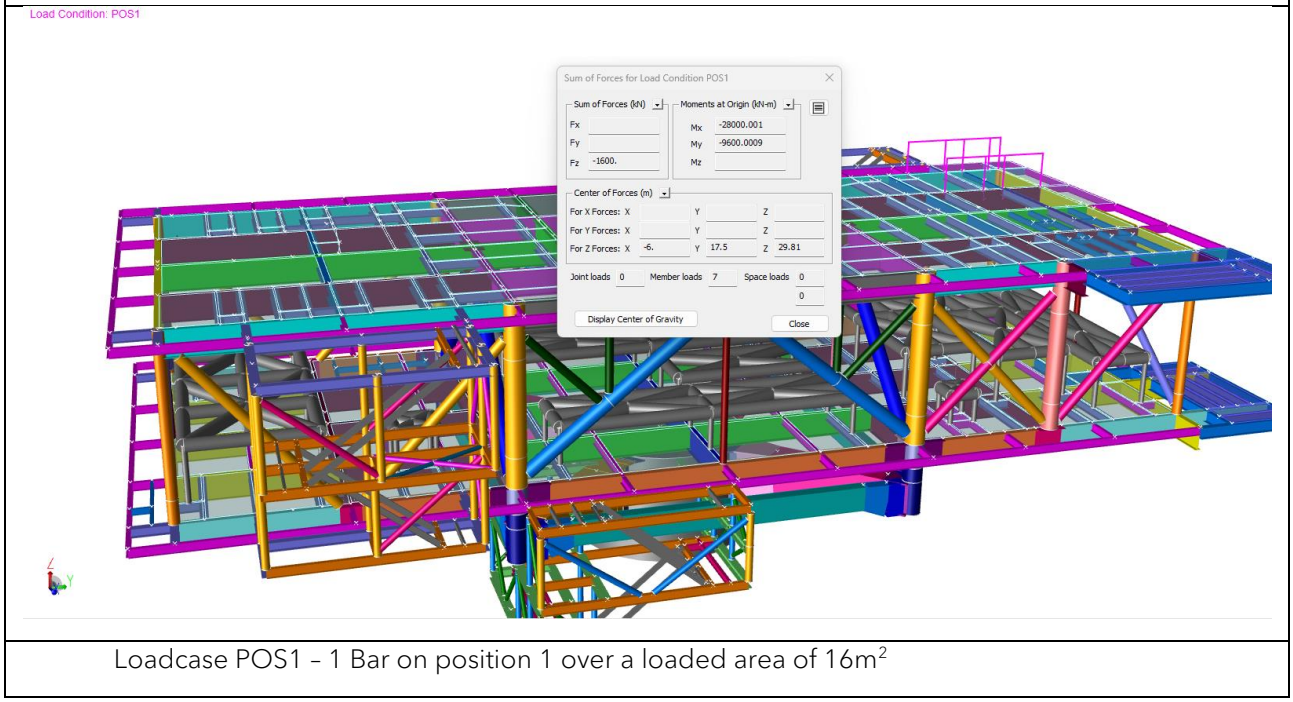
This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

11.3.1 Load cases and combinations

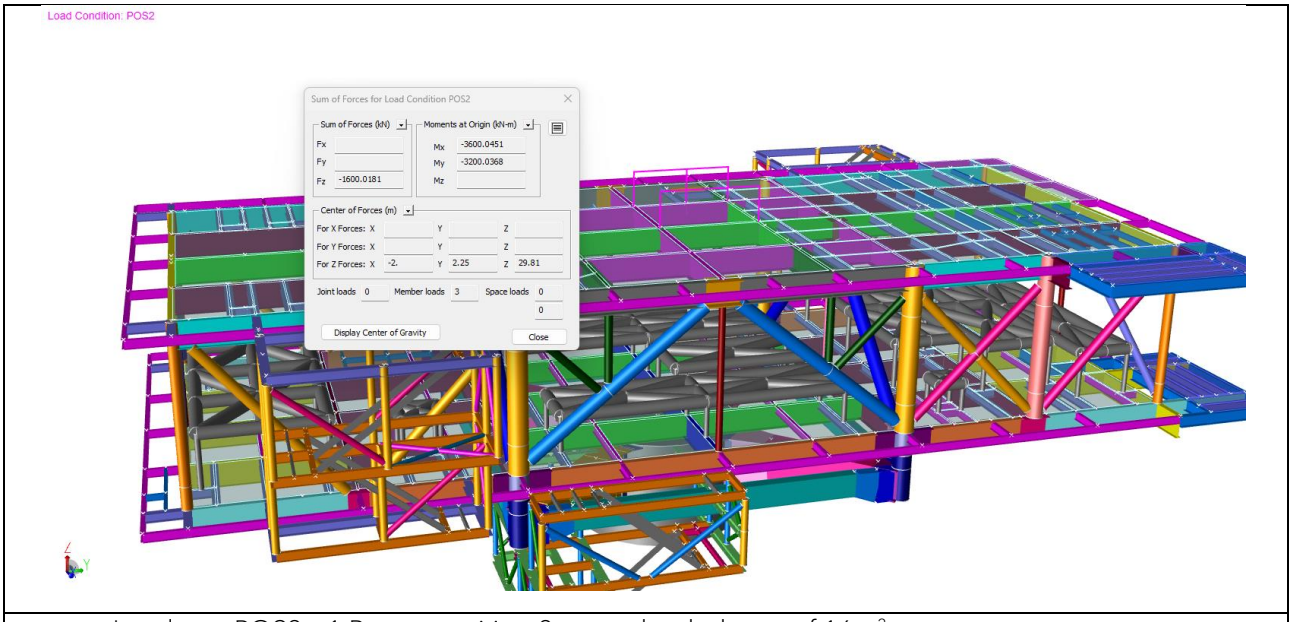
The following plots show the various load cases used in the analysis.



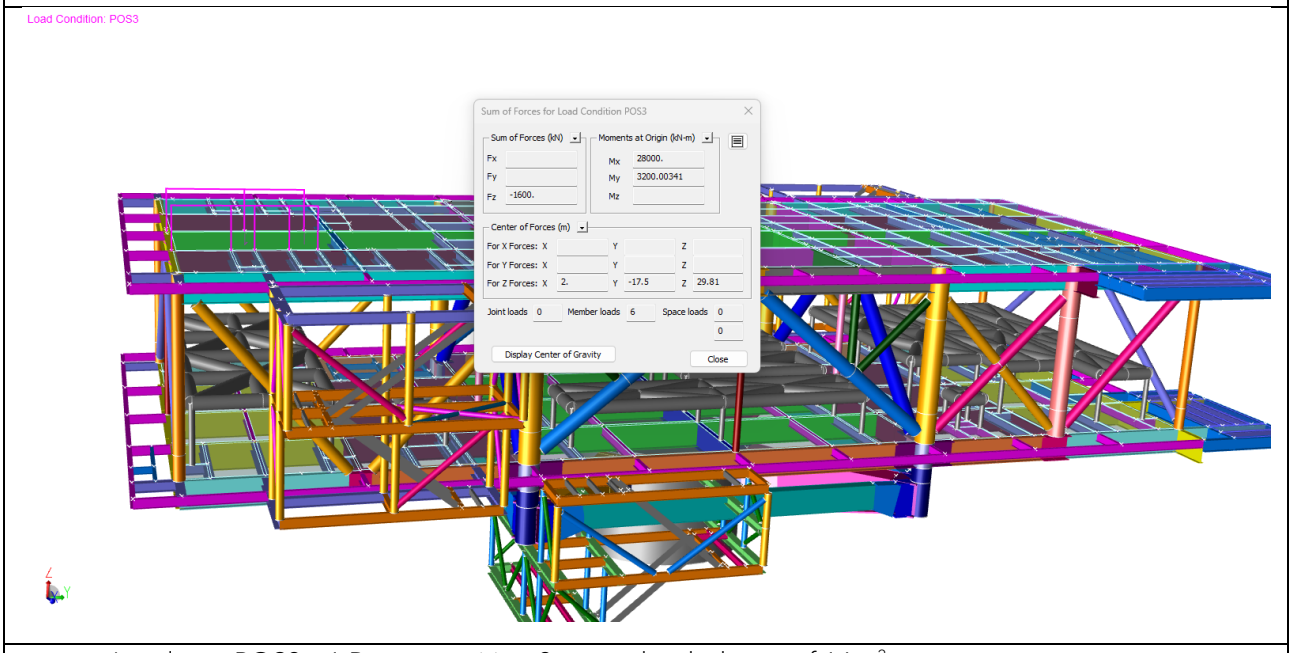
Loadcase STAT – Topsides dry weight



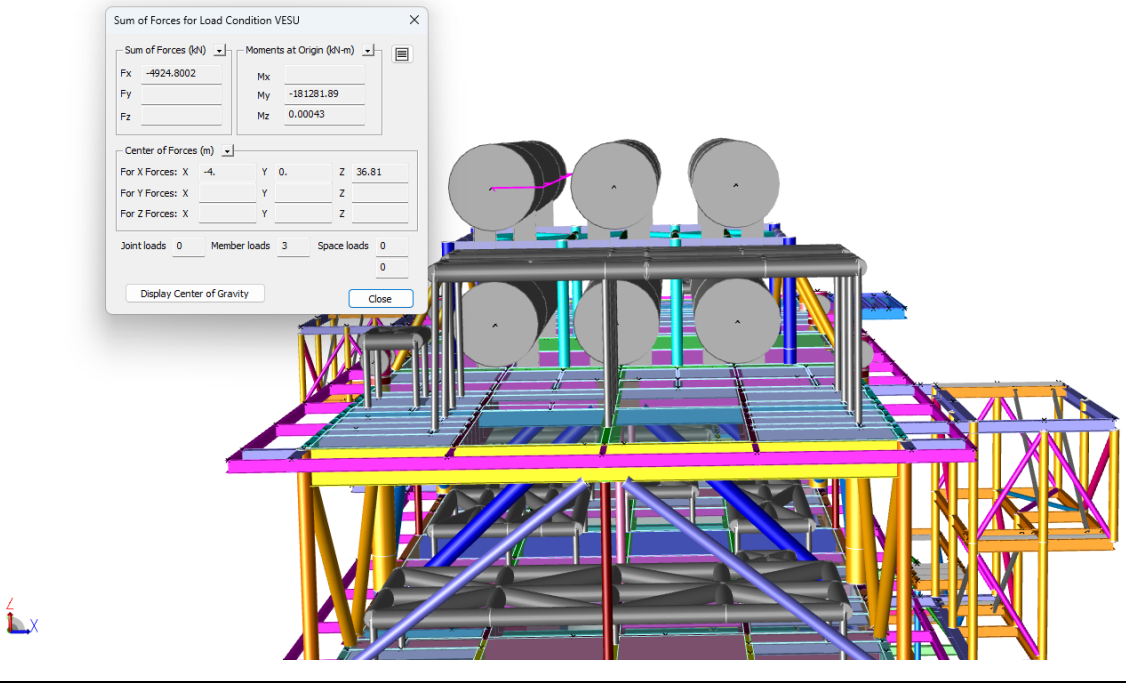
Loadcase POS1 – 1 Bar on position 1 over a loaded area of 16m^2



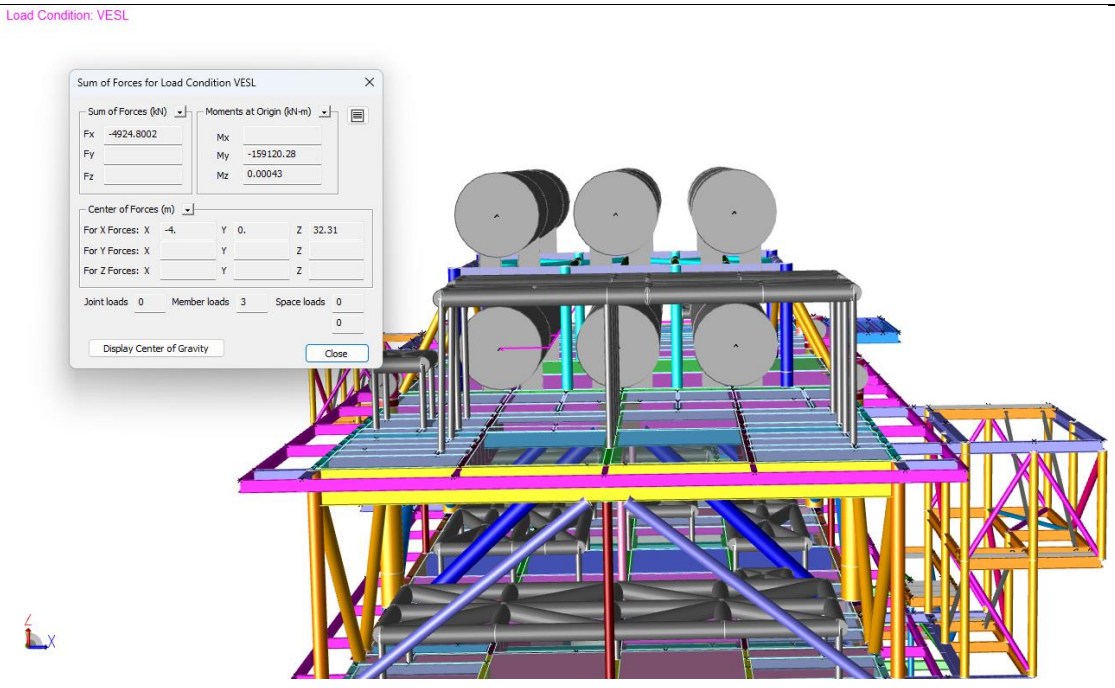
Loadcase POS2 – 1 Bar on position 2 over a loaded area of 16m^2



Loadcase POS3 – 1 Bar on position 3 over a loaded area of 16m^2



Loadcase VESU – 1 Bar on full vessel projected area (upper level)



Loadcase VESL – 1 Bar on full vessel projected area (lower level)

The basic load condition resultants are reported here below:

****** SEASTATE BASIC LOAD CASE SUMMARY ******
RELATIVE TO MUDLINE ELEVATION

LOAD CASE	LOAD LABEL	FX (KN)	FY (KN)	FZ (KN)	MX (KN-M)	MY (KN-M)	MZ (KN-M)	DEAD LOAD (KN)	MARINE METHOD BUOYANCY (KN)
1	VESU	-4924.80	0.00	0.00	0.0	-181281.9	0.0	0.00	0.00
2	G001	0.00	0.00	-20982.66	433.1	1958.3	0.0	0.00	0.00
3	POS1	0.00	0.00	-1600.00	-28000.0	-9600.0	0.0	0.00	0.00
4	POS2	0.00	0.00	-1600.02	-3600.0	-3200.0	0.0	0.00	0.00
5	POS3	0.00	0.00	-1600.00	28000.0	3200.0	0.0	0.00	0.00
6	STAT	0.00	0.00	-21602.91	1878.6	2041.8	0.0	0.00	0.00
7	VESL	-4924.80	0.00	0.00	0.0	-159120.3	0.0	0.00	0.00

11.3.2 Load combinations

The following load combinations have been analysed.

Load combination ID	Description	STAT	POS1	POS2	POS3	VESL	VESU
1BP1	1 Bar Position 1	1.09	1.0				
2BP1	2 Bar Position 1	1.09	2.0				
1BP2	1 Bar Position 2	1.09		1.0			
2BP2	2 Bar Position 2	1.09		2.0			
1BP3	1 Bar Position 3	1.09			1.0		
2BP3	2 Bar Position 3	1.09			2.0		
1BVL	1 Bar Lower vessel					1.0	
09VU	0.9 Bar Upper vessel						0.9

***** SEASTATE COMBINED LOAD CASE SUMMARY *****
RELATIVE TO MUDLINE ELEVATION

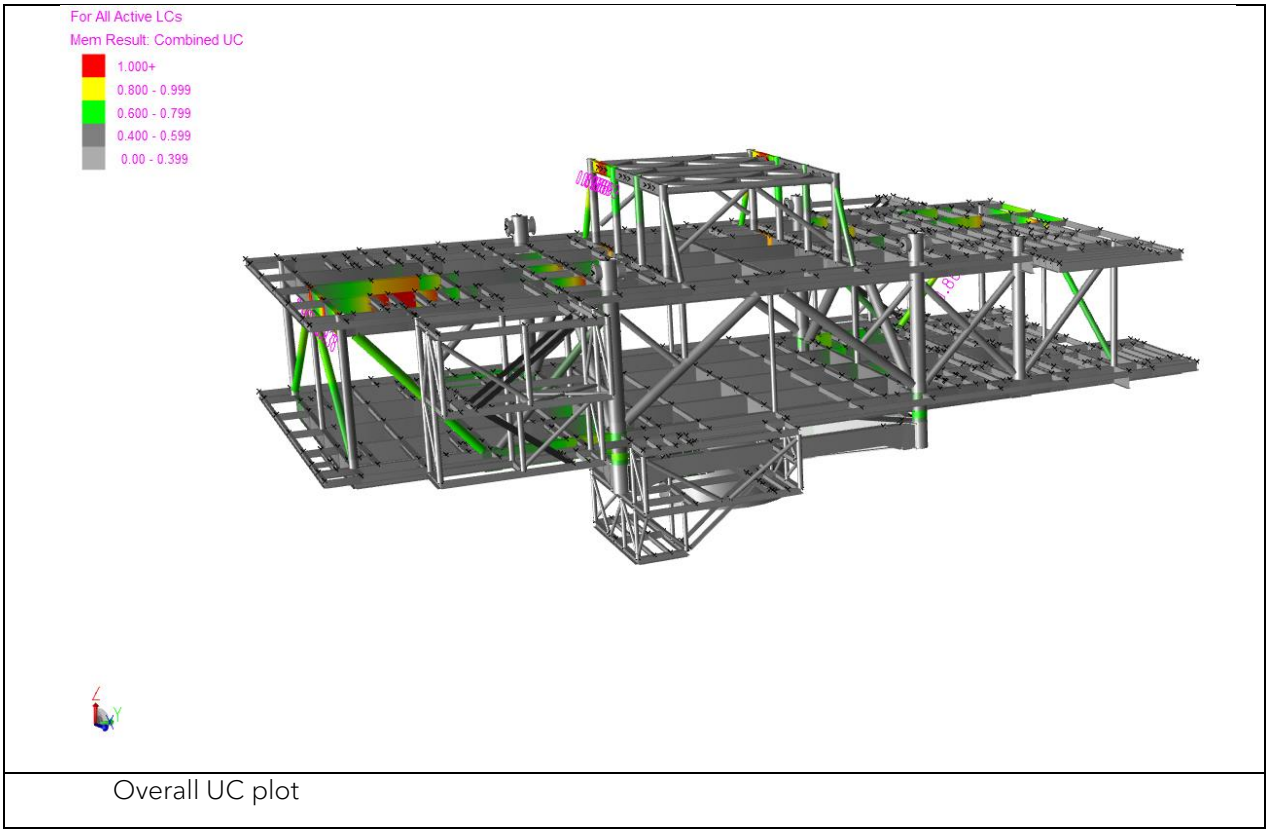
LOAD CASE	LOAD LABEL	FX (KN)	FY (KN)	FZ (KN)	MX (KN-M)	MY (KN-M)	MZ (KN-M)
8	1BP1	0.00	0.00	-25147.18	-25952.4	-7374.4	0.0
9	1BP2	0.00	0.00	-25147.20	-1552.4	-974.5	0.0
10	1BP3	0.00	0.00	-25147.18	30047.7	5425.6	0.0
11	2BP1	0.00	0.00	-26747.18	-53952.4	-16974.5	0.0
12	2BP2	0.00	0.00	-26747.21	-5152.5	-4174.5	0.0
13	2BP3	0.00	0.00	-26747.18	58047.7	8625.6	0.0
14	09VU	-4432.32	0.00	-23547.18	2047.6	-160928.2	0.0
15	1BVL	-4924.80	0.00	-23547.18	2047.6	-156894.8	0.0

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

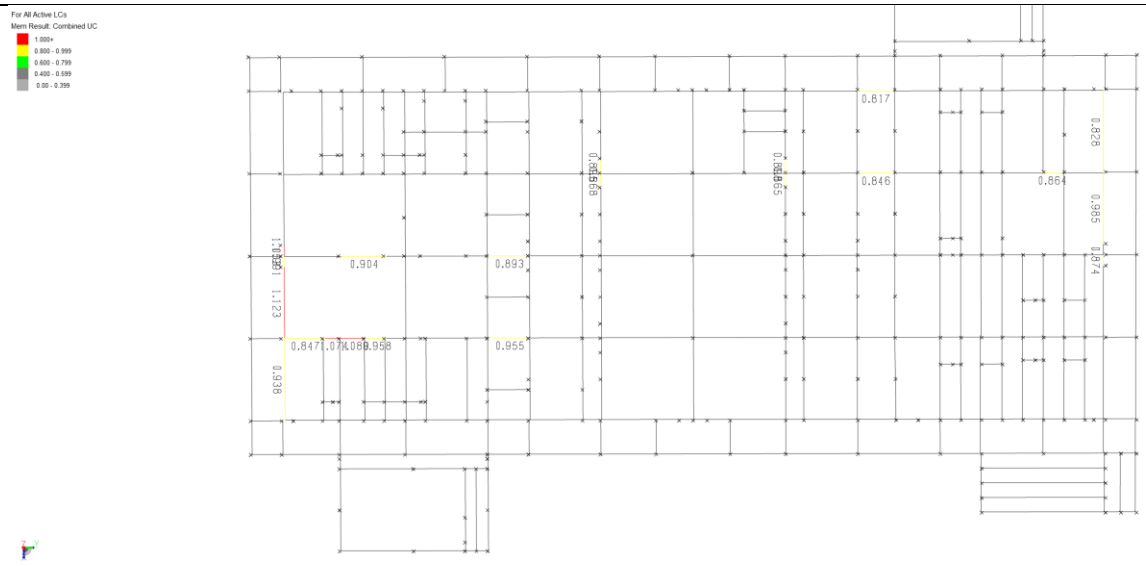
11.3.3 Results from the static checks

The code checks performed show that the structure can withstand the high local overpressures.

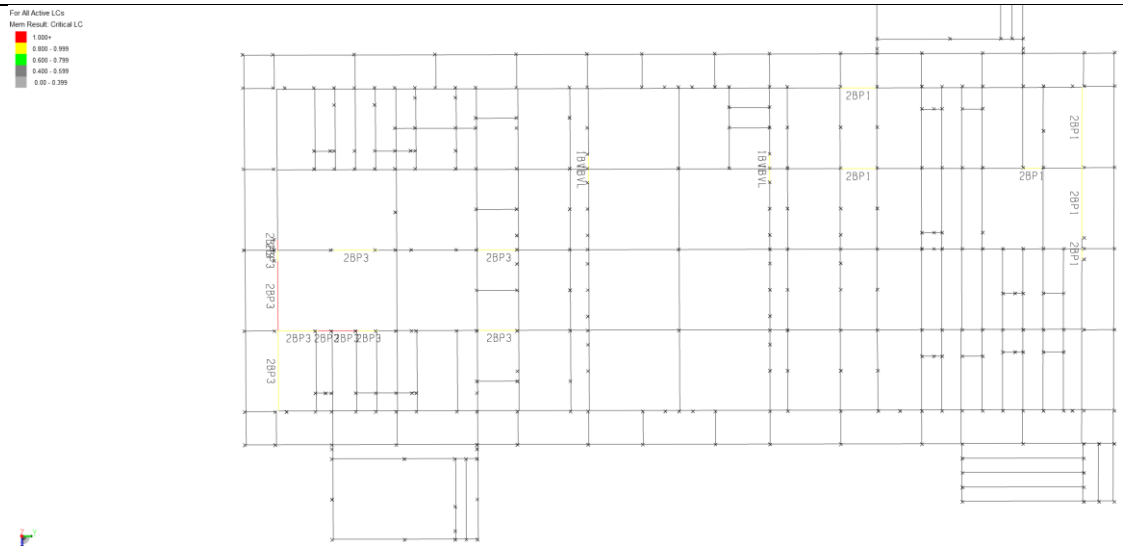
Only a few unity checks exceed 1.0 for the 2 bar case on position 3, all other load combination result in unity checks below 1.0. This is considered acceptable for the conservative 2Bar cases, especially when combined with the dynamic amplification factors calculated which are <1.0.



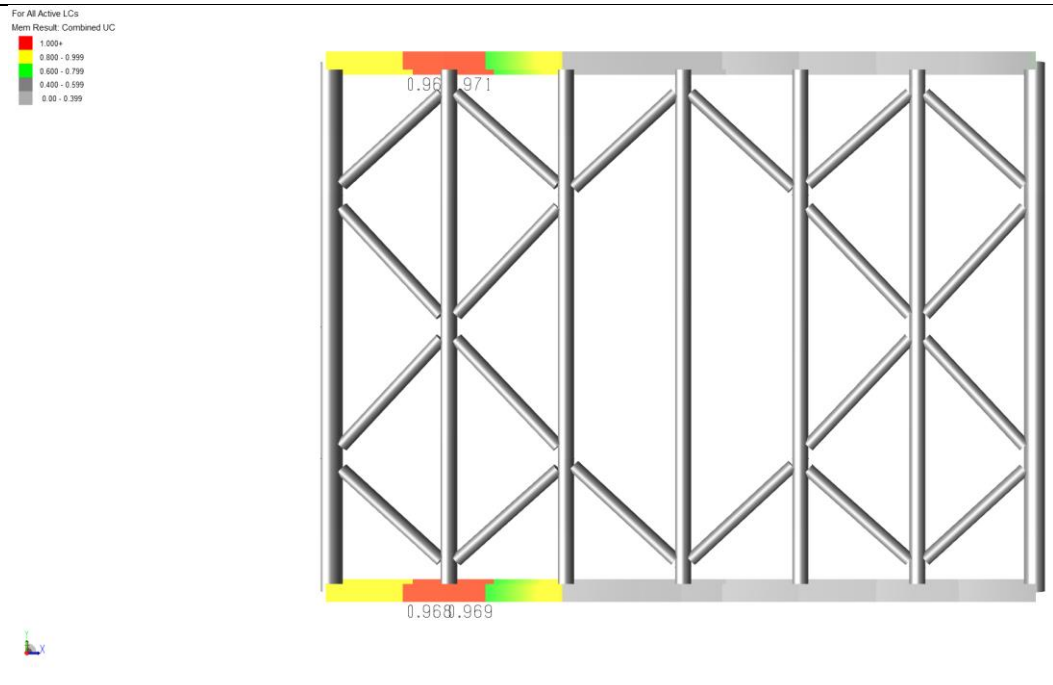
Overall UC plot



Upper deck unity check plot



Upper deck critical loadcases



Upper vessel support frame unity checks.

The SACS results for all elements with 0.8 < UC < 1.1.

```
SACS CONNECT Edition V(16.0) - CL                                   Company: Shell Nederland B.V.
     TECON - BLPH TOPSIDE & TRANSITION PIECE - IN-SERVICE ANALYSIS rev.1     DATE 14-NOV-2024  TIME 16:59:06   PST PAGE  1227

                                   SACS-IV   MEMBER UNITY CHECK RANGE SUMMARY

                                GROUP II  - UNITY CHECKS GREATER THAN    0.90 AND LESS THAN    1.10
```

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
U081-U127	B12	0.904	2BP3	1.1	17.66	249.04	0.46	-1.24	-34.24	29.1	68.0	0.622	1BP3	0.378	09VU
U123-U182	B13	1.089	2BP3	0.7	9.55	215.13	-4.09	7.04	12.28	30.1	96.6	0.658	1BP3	0.256	09VU
U178-U123	B13	1.074	2BP3	0.8	4.46	213.00	-10.23	21.07	245.18	30.1	96.6	0.640	1BP3	0.238	09VU
U182-U128	B13	0.958	2BP3	0.0	15.12	202.92	-1.17	6.46	-162.07	30.1	96.6	0.588	1BP3	0.250	09VU
U188-U002	B13	0.955	2BP3	2.0	8.51	-225.08	-17.73	-7.44	-587.54	30.1	96.6	0.657	1BP3	0.447	2BP2
U006-U069	B14	0.991	2BP3	0.5	-79.79	-100.77	-11.20	1.77	-371.24	21.1	86.4	0.671	1BP3	0.367	2BP1
U007-U008	B14	0.938	2BP3	0.0	-5.64	270.37	-33.92	7.10	-512.81	21.1	86.4	0.535	1BP3	0.148	2BP1
U019-U057	B14	0.985	2BP1	0.0	-11.95	290.82	-7.06	1.30	-697.37	21.1	86.4	0.606	1BP1	0.228	09VU
H238-P105	PB1	0.968	09VU	0.7	-9.28	-23.16	0.88	2.63	-2135.29	15.9	28.3	0.147	2BP2	0.137	1BP2
H241-P106	PB1	0.969	09VU	0.7	-9.65	-23.51	-0.85	-2.23	-2138.66	15.9	28.3	0.192	2BP2	0.156	1BP2
P105-H239	PB1	0.969	09VU	0.7	-10.48	-285.76	0.70	-0.23	-2139.31	15.9	28.3	0.238	2BP2	0.193	1BP2
P106-H240	PB1	0.971	09VU	0.7	-11.10	-286.54	-0.66	0.25	-2142.83	15.9	28.3	0.240	2BP2	0.194	1BP2

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

The SACS results for all elements with UC > 1.1

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP III - UNITY CHECKS GREATER THAN 1.10 AND LESS THAN 999.00

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
U068-U006	B14	1.153	2BP3	0.0	-83.30	-147.03	-9.50	-1.23	1137.26	21.1	86.4	0.761	1BP3	0.404	09VU
U069-U007	B14	1.123	2BP3	3.5	-26.38	304.83	-1.04	-1.11	650.27	21.1	86.4	0.678	1BP3	0.260	1BVL

All unity checks >1.0 are coming from 2B## loadcases and thus 2 bar over pressures, the second highest unity check is less than 1.0 for all other cases.

The joint can check all have unity checks below 1.0.

* * J O I N T C A N S U M M A R Y * *

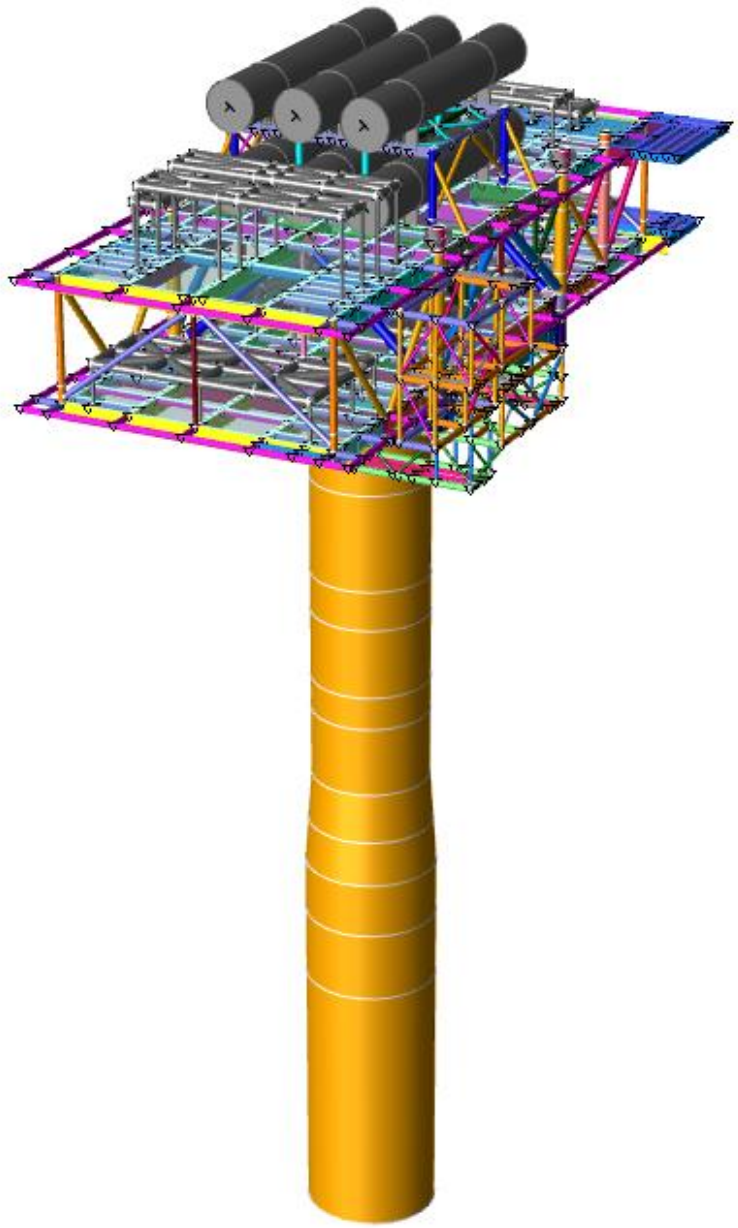
(UNITY CHECK ORDER)

	ORIGINAL					LOAD DESIGN					STRENGTH ANALYSIS		
JOINT	DIAMETER (CM)	THICKNESS (CM)	YLD STRS (N/MM2)	LOAD UC	STRN UC	DIAMETER (CM)	THICKNESS (CM)	YLD STRS (N/MM2)	LOAD UC	STRN UC	BRACE JOINT	LOAD CASE
U015	80.000	3.000	400.000	0.590	0.590	80.000	3.000	400.000	0.590	0.590	L113	2BP1
U003	80.000	3.000	400.000	0.537	0.537	80.000	3.000	400.000	0.537	0.537	L033	2BP3
D004	55.000	2.000	400.000	0.510	0.510	55.000	2.000	400.000	0.510	0.510	U023	2BP2
P104	45.720	1.905	355.000	0.508	0.508	45.720	1.905	355.000	0.508	0.508	U023	09VU
P101	45.720	1.905	355.000	0.506	0.506	45.720	1.905	355.000	0.506	0.506	U040	09VU
D003	55.000	2.000	400.000	0.445	0.445	55.000	2.000	400.000	0.445	0.445	U040	09VU
U005	80.000	3.000	400.000	0.434	0.434	80.000	3.000	400.000	0.434	0.434	L110	2BP3
L010	40.640	2.144	355.000	0.434	0.434	40.640	2.144	355.000	0.434	0.434	U068	2BP3
D006	55.000	2.000	400.000	0.385	0.385	55.000	2.000	400.000	0.385	0.385	U022	2BP2
P102	45.720	1.905	355.000	0.368	0.368	45.720	1.905	355.000	0.368	0.368	U021	VESU
P103	45.720	1.905	355.000	0.368	0.368	45.720	1.905	355.000	0.368	0.368	U022	VESU
L008	40.640	2.144	355.000	0.367	0.367	40.640	2.144	355.000	0.367	0.367	U069	2BP3
0002	40.640	2.062	355.000	0.362	0.362	40.640	2.062	355.000	0.362	0.362	L156	2BP1
L018	40.640	2.144	355.000	0.347	0.347	40.640	2.144	355.000	0.347	0.347	U067	2BP1
U045	70.000	3.000	400.000	0.294	0.294	70.000	3.000	400.000	0.294	0.294	0002	2BP1
L156	70.000	3.000	400.000	0.283	0.283	70.000	3.000	400.000	0.283	0.283	U153	2BP1
D005	55.000	2.000	400.000	0.261	0.261	55.000	2.000	400.000	0.261	0.261	U021	2BP2
L013	80.000	4.000	400.000	0.241	0.241	80.000	4.000	400.000	0.241	0.241	D006	2BP1
L005	80.000	4.000	400.000	0.228	0.228	80.000	4.000	400.000	0.228	0.228	D003	2BP3
U013	80.000	3.000	400.000	0.225	0.225	80.000	3.000	400.000	0.225	0.225	0002	2BP1
L015	80.000	4.000	400.000	0.199	0.199	80.000	4.000	400.000	0.199	0.199	D004	2BP2
L003	80.000	4.000	400.000	0.164	0.164	80.000	4.000	400.000	0.164	0.164	D005	2BP3
L020	40.640	2.144	355.000	0.154	0.154	40.640	2.144	355.000	0.154	0.154	U057	09VU
P112	35.500	1.588	355.000	0.132	0.132	35.500	1.588	355.000	0.132	0.132	P002	VESU
P123	35.500	1.588	355.000	0.123	0.123	35.500	1.588	355.000	0.123	0.123	P146	VESU
P122	35.500	1.588	355.000	0.122	0.122	35.500	1.588	355.000	0.122	0.122	P149	VESU
P111	35.500	1.588	355.000	0.119	0.119	35.500	1.588	355.000	0.119	0.119	P001	09VU
P137	27.310	1.588	355.000	0.116	0.116	27.310	1.588	355.000	0.116	0.116	P145	VESU
P140	27.310	1.588	355.000	0.116	0.116	27.310	1.588	355.000	0.116	0.116	P148	VESU
P121	35.500	1.588	355.000	0.108	0.108	35.500	1.588	355.000	0.108	0.108	P144	2BP2
P120	35.500	1.588	355.000	0.095	0.095	35.500	1.588	355.000	0.095	0.095	P147	2BP2
P139	27.310	1.588	355.000	0.065	0.065	27.310	1.588	355.000	0.065	0.065	P148	VESU
P138	27.310	1.588	355.000	0.064	0.064	27.310	1.588	355.000	0.064	0.064	P145	VESU
P118	27.310	1.588	355.000	0.051	0.051	27.310	1.588	355.000	0.051	0.051	P122	09VU
P119	27.310	1.588	355.000	0.045	0.045	27.310	1.588	355.000	0.045	0.045	P121	2BP2
U00L	40.640	1.588	355.000	0.042	0.042	40.640	1.588	355.000	0.042	0.042	P137	09VU
U00J	40.640	1.588	355.000	0.040	0.040	40.640	1.588	355.000	0.040	0.040	P140	VESU
U00K	40.640	1.588	355.000	0.025	0.025	40.640	1.588	355.000	0.025	0.025	P138	VESU
U00I	40.640	1.588	355.000	0.025	0.025	40.640	1.588	355.000	0.025	0.025	P139	VESU

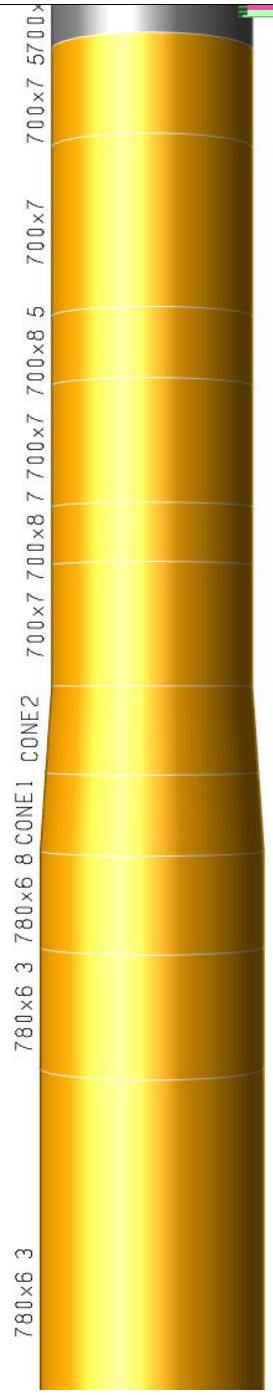
This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

11.4 DYNAMIC SIMULATION

A dynamic model was generated with the monopile. The monopile was fixed at 1.5D below the mudline.



Model isometric



Properties of modelled monopile (in cm)

11.4.1 Mode shapes and mass participation

The natural frequencies of the first 10 modes are listed below, in total 100 modes are included in the model. The mass participation factors are listed below as well.

SACS IV-FREQUENCIES AND GENERALIZED MASS

MODE	FREQ.(CPS)	GEN. MASS	EIGENVALUE	PERIOD(SECS)
1	0.507142	1.8190773E+03	9.8487546E-02	1.9718349
2	0.525624	1.2368972E+03	9.1683233E-02	1.9025008
3	1.067526	1.7864837E+02	2.2227109E-02	0.9367450
4	1.700094	7.0123249E+01	8.7638429E-03	0.5882029
5	1.780404	1.3923043E+01	7.9910391E-03	0.5616704
6	1.879216	2.8574627E+02	7.1727714E-03	0.5321369
7	2.113996	4.5386612E-01	5.6680266E-03	0.4730378
8	2.122234	4.5285110E-01	5.6241077E-03	0.4712015
9	2.214603	2.0558102E+01	5.1647423E-03	0.4515483
10	2.289040	1.2484263E+01	4.8342989E-03	0.4368644

MASS PARTICIPATION FACTOR REPORT

BASED ON EXPANDED DEGREES OF FREEDOM

	******* MASS PARTICIPATION FACTORS *******			***** CUMULATIVE FACTORS *****		
MODE	X	Y	Z	X	Y	Z
1	0.0005563	0.5548818	0.0000071	0.000556	0.554882	0.000007
2	0.5987535	0.0006127	0.0000027	0.599310	0.555494	0.000010
3	0.0013558	0.0000019	0.0000015	0.600666	0.555496	0.000011
4	0.0000003	0.0033490	0.0000042	0.600666	0.558845	0.000015
5	0.0070569	0.0019544	0.0000818	0.607723	0.560800	0.000097
6	0.0000114	0.1561123	0.0006138	0.607734	0.716912	0.000711
7	0.0000765	0.0000003	0.0000021	0.607811	0.716912	0.000713
8	0.0000000	0.0000000	0.0000000	0.607811	0.716912	0.000713
9	0.0000378	0.0065212	0.0003491	0.607849	0.723434	0.001062
10	0.0001181	0.0190470	0.0000488	0.607967	0.742481	0.001111
11	0.0000104	0.0000076	0.0000013	0.607977	0.742488	0.001112
12	0.0012306	0.0052148	0.0066403	0.609208	0.747703	0.007753
13	0.2130794	0.0002211	0.0000010	0.822287	0.747924	0.007754
14	0.0000367	0.0008713	0.4587281	0.822324	0.748795	0.466482
15	0.0000029	0.0006291	0.0020025	0.822327	0.749424	0.468484
16	0.0010277	0.0057608	0.0127584	0.823354	0.755185	0.481243
17	0.0000329	0.0043851	0.0580177	0.823387	0.759570	0.539260
18	0.0056257	0.0004059	0.0000507	0.829013	0.759976	0.539311
19	0.0000021	0.0010238	0.0001107	0.829015	0.761000	0.539422
20	0.0001381	0.0046919	0.0057078	0.829153	0.765692	0.545130
21	0.0000426	0.0297076	0.0053103	0.829196	0.795399	0.550440
22	0.0179239	0.0007038	0.0000255	0.847120	0.796103	0.550465
23	0.0023263	0.0016770	0.0000744	0.849446	0.797780	0.550540
24	0.0001092	0.0642284	0.0000208	0.849555	0.862009	0.550561
25	0.0005599	0.0316558	0.0009184	0.850115	0.893665	0.551479
26	0.0032864	0.0037042	0.0000291	0.853402	0.897369	0.551508
27	0.0063062	0.0011118	0.0000101	0.859708	0.898480	0.551518
28	0.0043292	0.0002748	0.0000049	0.864037	0.898755	0.551523
29	0.0000128	0.0258002	0.0001244	0.864050	0.924556	0.551648
30	0.0010241	0.0057958	0.0000048	0.865074	0.930351	0.551652
31	0.0001034	0.0051645	0.0000306	0.865177	0.935516	0.551683
32	0.0166697	0.0000098	0.0001697	0.881847	0.935526	0.551853
33	0.0030410	0.0076123	0.0005234	0.884888	0.943138	0.552376
34	0.0046945	0.0001861	0.0002138	0.889583	0.943324	0.552590
35	0.0228289	0.0003028	0.0000215	0.912411	0.943627	0.552611
36	0.0063404	0.0000023	0.0000002	0.918752	0.943629	0.552612

37	0.0131772	0.0012660	0.0001377	0.931929	0.944895	0.552749
38	0.0008570	0.0013239	0.0000025	0.932786	0.946219	0.552752
39	0.0115593	0.0003283	0.0001989	0.944345	0.946547	0.552951
40	0.0023803	0.0000344	0.0000644	0.946726	0.946582	0.553015
41	0.0026334	0.0002819	0.0000198	0.949359	0.946864	0.553035
42	0.0033610	0.0007483	0.0005028	0.952720	0.947612	0.553538
43	0.0000765	0.0015629	0.0007578	0.952797	0.949175	0.554296
44	0.0000727	0.0049800	0.0015083	0.952869	0.954155	0.555804
45	-0.0000026	0.0003503	0.0000327	0.952867	0.954505	0.555836
46	0.0000189	0.0001253	0.0007781	0.952885	0.954630	0.556615
47	0.0000435	0.0000089	0.0000016	0.952929	0.954639	0.556616
48	0.0002156	0.0002961	0.0000191	0.953145	0.954935	0.556635
49	0.0003038	0.0004717	0.0006805	0.953448	0.955407	0.557316
50	0.0001832	0.0003211	0.0003013	0.953632	0.955728	0.557617
51	0.0016423	0.0001585	0.0000129	0.955274	0.955887	0.557630
52	0.0000571	0.0003289	0.0000027	0.955331	0.956216	0.557633
53	0.0000305	0.0000246	0.0000419	0.955361	0.956240	0.557675
54	0.0000471	0.0000014	0.0022585	0.955409	0.956242	0.559933
55	-0.0000066	0.0000059	0.0009219	0.955402	0.956248	0.560855
56	0.0004144	0.0000000	0.0000049	0.955816	0.956248	0.560860
57	0.0002586	0.0000915	0.0017680	0.956075	0.956339	0.562628
58	0.0002404	0.0000005	0.0001065	0.956315	0.956340	0.562734
59	0.0000620	0.0000013	0.0000110	0.956377	0.956341	0.562745
60	0.0000909	0.0000182	0.0001439	0.956468	0.956359	0.562889
61	0.0001374	0.0000028	0.0001070	0.956606	0.956362	0.562996
62	0.0001150	0.0000131	0.0000009	0.956721	0.956375	0.562997
63	0.0000097	0.0000022	0.0001261	0.956730	0.956377	0.563123
64	0.0000000	0.0000000	0.0000000	0.956730	0.956377	0.563123
65	0.0004907	0.0000134	0.0017575	0.957221	0.956391	0.564881
66	0.0000170	0.0000000	0.0000204	0.957238	0.956391	0.564901
67	0.0000334	0.0000019	0.0006480	0.957271	0.956393	0.565549
68	0.0000226	0.0000001	0.0006137	0.957294	0.956393	0.566163
69	0.0000158	0.0000299	0.0000125	0.957310	0.956423	0.566176
70	0.0001266	0.0000121	0.0000060	0.957436	0.956435	0.566182
71	0.0001285	0.0001133	0.0022575	0.957565	0.956548	0.568439
72	0.0007619	0.0000112	0.0069673	0.958327	0.956559	0.575406
73	0.0023542	-0.0000001	0.0013888	0.960681	0.956559	0.576795
74	0.0000875	0.0000418	0.0017518	0.960768	0.956601	0.578547
75	0.0002675	0.0002398	0.0024346	0.961036	0.956841	0.580981
76	0.0000354	0.0000477	0.0003963	0.961071	0.956888	0.581378
77	0.0001080	0.0000325	0.0000044	0.961179	0.956921	0.581382
78	0.0003192	0.0000047	0.0035145	0.961499	0.956926	0.584897
79	0.0000149	0.0000974	0.0005627	0.961513	0.957023	0.585459
80	0.0013233	0.0000329	0.0002264	0.962837	0.957056	0.585686
81	0.0001335	0.0000085	0.0000044	0.962970	0.957065	0.585690
82	0.0003844	0.0000004	0.0000032	0.963355	0.957065	0.585693
83	0.0000207	0.0001098	0.0000060	0.963375	0.957175	0.585699
84	0.0003193	0.0000258	0.0000040	0.963695	0.957201	0.585703
85	0.0000091	0.0005744	0.0000268	0.963704	0.957775	0.585730
86	0.0002700	0.0011629	0.0000022	0.963974	0.958938	0.585732
87	0.0000086	0.0008339	0.0000008	0.963982	0.959772	0.585733
88	0.0000044	0.0003295	0.0000413	0.963987	0.960101	0.585774
89	0.0002739	0.0002577	0.0002020	0.964261	0.960359	0.585977
90	0.0001299	0.0006370	0.0000193	0.964391	0.960996	0.585996
91	0.0000062	0.0011591	0.0000098	0.964397	0.962155	0.586006
92	0.0002401	0.0005213	0.0001169	0.964637	0.962676	0.586123
93	0.0001338	0.0025461	0.0000000	0.964771	0.965222	0.586123
94	0.0002109	0.0000165	0.0000090	0.964982	0.965239	0.586132
95	0.0000896	0.0001648	0.0001467	0.965071	0.965404	0.586278
96	0.0003390	0.0000265	0.0000263	0.965410	0.965430	0.586305
97	0.0002607	0.0011296	0.0000011	0.965671	0.966560	0.586306
98	0.0007570	0.0000022	0.0000510	0.966428	0.966562	0.586357
99	0.0005356	0.0001868	0.0001100	0.966964	0.966749	0.586467
100	0.0007958	0.0004936	0.0000757	0.967759	0.967242	0.586542

*** EFFECTIVE WEIGHT X 48741.230 KN

Y 48741.230 KN

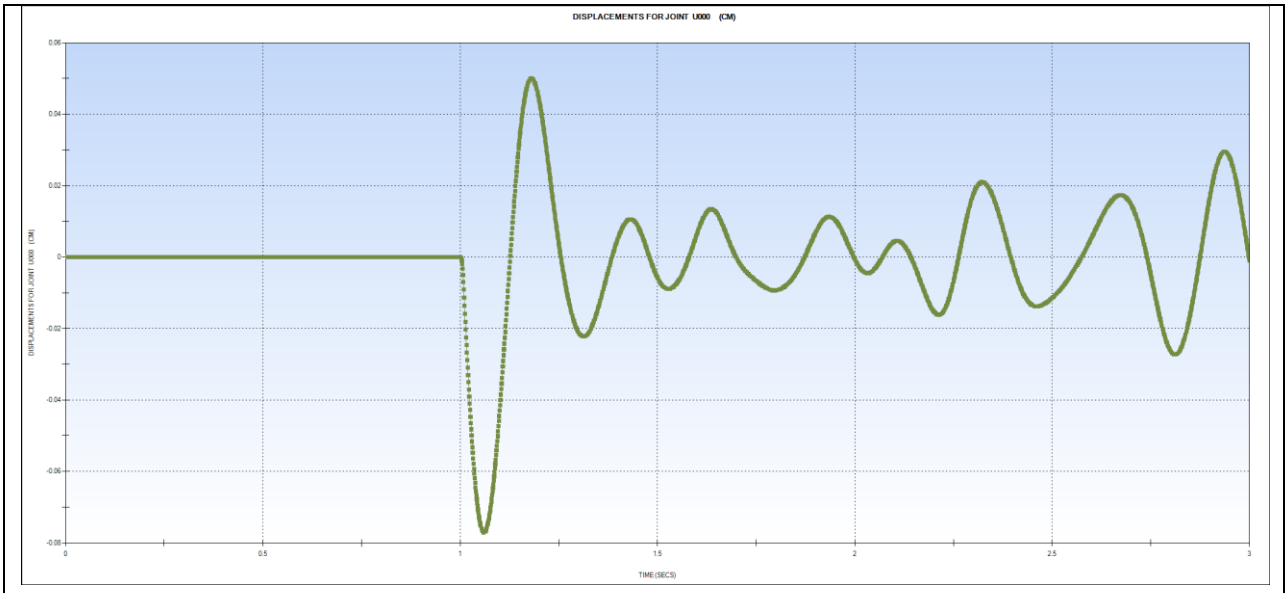
Z 37343.257 KN

11.4.2 Dynamic Response

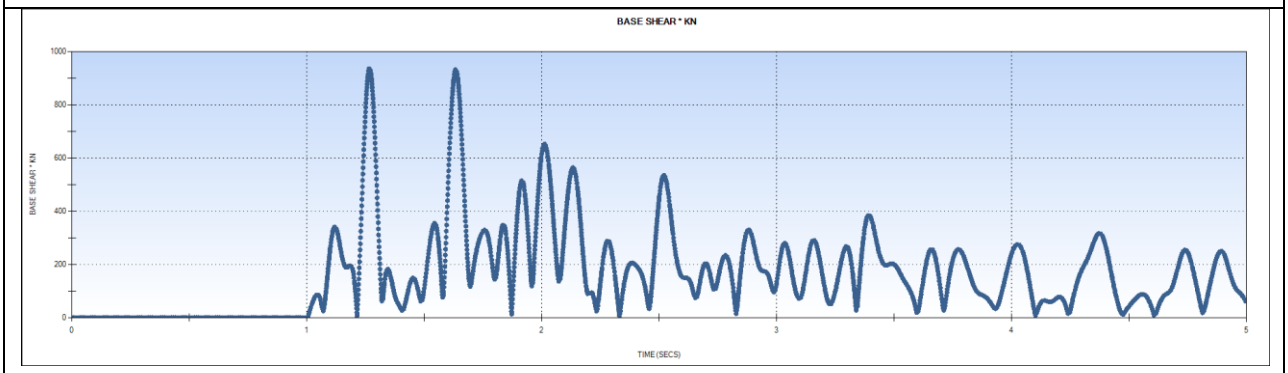
To see the impact of the dynamics, a dynamic response was calculated for the position 2 blast load on the upper deck and the lateral blast on the upper storage vessels.

The input loads for the vertical blast is 1600kN (16m^2 x 100kN/m^2) and the vessel was loaded at the centerline with 5000kN (rounded up from the VESU static loadcase).

The hydrogen blast is taken as a triangular load profile with a total duration of 10ms and a 5ms rise time.



Vertical displacement of joint U000



Total base shear for the blast on the upper vessel.

The static displacement of joint U000 for loadcase POS2 is: 0.08cm

JOINT DISPLACEMENTS AND ROTATIONS REPORT

JOINT	LOAD COND	********* DEFL(X)	CM DEFL(Y)	********** DEFL(Z)	********* ROT(X)	RAD ROT(Y)	********* ROT(Z)
U000	POS2	-0.0696	0.0825	-0.9485	-0.0006	-0.0004	0.0000

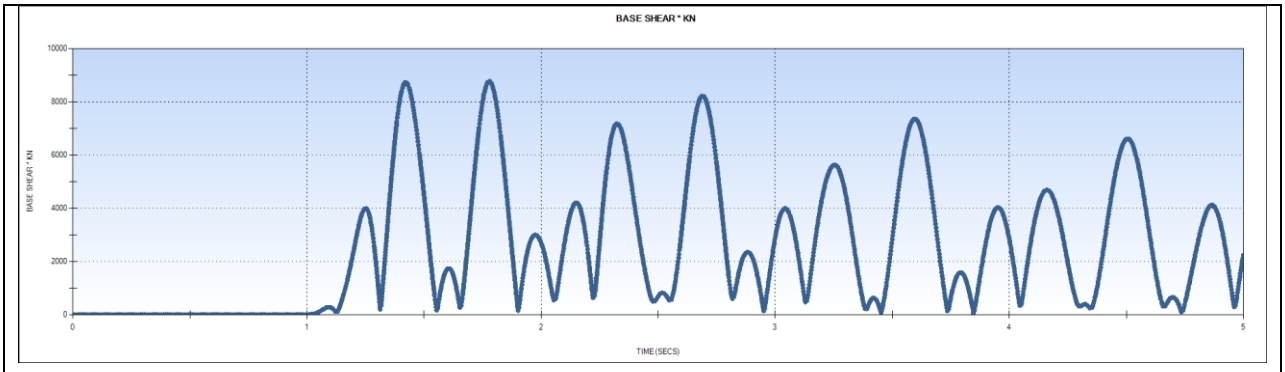
The DAF for the vertical blast is 0.08cm / 0.95cm = 0.08

The DAF for the horizontal blast is 935kN / 5000 kN = 0.19

The very short duration of the blast load leads to a blast load in the "Impulsive" regime, the structure doesn't have time to respond to the input loads.

The actual local dynamic blast overpressures the structure can withstand are 5 to 12 times higher than the loads checked in the static check.

As a sense check, a blast of 300ms duration was analyzed for the vessel blast, this case does results in a DAF of more than 1.



The DAF for 300ms would be 8768 kN / 5000 kN = 1.75

APPENDIX A ALARP WORKSHEET

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

Base Load Power Hub (BLPH)

ALARP Worksheets

DRAFT

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

Table of contents

1. Hydrogen release from single tank leading to escalation 3

DRAFT

1. HYDROGEN RELEASE FROM SINGLE TANK LEADING TO ESCALATION

IDENTIFY

Problem Definition

Hydrogen release from single H2 storage vessel with potential escalation to the other H2 storage vessels

HSSE Issues and Potential Risk

Ignited release of H_2 at one H_2 storage vessel leading to escalation to one of the other H2 storage vessels.

A potential scenario for escalation is a flange leak in one of the H_2 storage vessels, leading to a jet fire flame impingement at an adjacent structure.

The risk associated with escalation has been ranked as 3B (one storage vessel is around €1M, escalation towards 2 storage vessels has been assumed) and is not a major accident.

HSSE Standard and Tolerability Criteria

The risk is managed to tolerable by meeting standard design requirements and the tolerability criteria in the project's HSE design philosophy (Document Number: 123A90-DDL-SAF-RE-30046).

Note that the BLPH does not fall under the "mijnbouwwet" and the EU directive https://wetten.overheid.nl/BWBR0014168/2022-01-01

https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32013L0030

as these rules apply for storage below 100m underground and pipelines.

Note that the BLPH does not fall under the "Besluit risico's zware ongevallen 2015 - https://wetten.overheid.nl/BWBR0036791/2015-07-08", as there will be less than 5 ton of H_2 (see part 2 of https://eur-lex.europa.eu/legal-content/NL/TXT/?uri=CELEX:32012L0018).

ASSESS

Options Considered

3 different options have been proposed:

a) As per current design
b) Additional spacing between H2 storage vessels
c) PFP on structural elements around the H2 storage vessels

Basis for Selection & Uncertainties

UKOOA Decision Framework decision Context Type B selected. These scenarios have some risk uncertainty to them or involve some risk trade-offs. Application of codes and standards requires some extension through engineering judgment. Options will likely require risk based analysis to support the decision.

Expert judgement	Decision was taken by the project team.
Risk Based Analysis	Qualitative and Quantitative risk based analysis was part of the decision making.

DRAFT

	Option Discussion: the team agrees that the risk associated with the current design solution is ALARP.
	Justification for Chosen Option
	During the SELECT phase, this concern was initially raised, and a MEMO (416041-40751/MEMO-001) has been created with determined that the distance between the H2 storage vessels was sufficient. In the SELECT ALARP report a recommendations was given: "During the next phase, the basis for the leak size and the related distances between the hydrogen vessels shall be evaluated in more detail." During the DEFINE phase, this recommendation has been closed with the "leak size analysis report" (doc. no. K559-2254-SE-TEN-001) and a FERA (Document No: K559-2254-SE-REP-007). The distance between the H2 storage vessels have been considered ALARP. A key point to note is that the guidance for estimating hydrogen separation distances is geared towards land based hydrogen filling stations and is focused on distances from the entire hydrogen system to an external receptor. During the Execute phase, the FERA (doc. no. 123A90-DDL-SAF-RE-30020) has been updated to the latest design and the risk associated with fire and explosions from the hydrogen storage system is tolerable and ALARP for a 2 year test facility. In combination with process hazard studies (HAZOP/LOPA) [9] and the Bow-Tie in Attachment 4 option A is chosen as the risk of the current design is considered ALARP by the ALARP workshop team.
	Justification for Rejected Options (e.g. Options not incorporated as considered beyond ALARP)
	Option B, additional spacing between H2 storage vessels This option requires a larger platform with massive increased CAPEX, which is grossly disproportionate considering the risk for escalation is assesses as tolerable according to FERA (doc. no. 123A90-DDL-SAF-RE-30020), QRA (doc. no. 123A90-DDL-SAF-RE-30019) and leak size analysis (doc. no. K559-2254-SE-TEN-001). **Option C – PFP on structural elements around the H2 storage vessels** PFP requires an investment of around €80.000 and reduces the fire escalation risk. The potential risk for fire escalation is already below 10^{-4}/yr according to FERA (doc. no. 123A90-DDL-SAF-RE-30020) and leak size analysis (doc. no. K559-2254-SE-TEN-001). The specific directionally has not been taken into account and would reduce the frequency of escalation even further. Normally a Cost Benefit Analysis (CBA) is only performed for MAH. However, for this escalation event, a CBA is performed for PFP. BenefitRR = The statistic value generated in reducing the risk over the period under consideration. BenefitRR [€/year] = (ΔCA + ΔCP + ΔCE) + (ΔCF x FGD)

DRAFT

	• ΔCA = The cost of asset damage avoided over the period under consideration
	  • Assuming PFP would eliminate the fire escalation would lead to a frequency of $<10^{-4}$/yr
	  • Assuming loss of 2 additional storage vessels" with a value of €1M each (€2M total)
	  • ΔCA = €2M * 10^{-4}/yr = €200/yr
	• ΔCP = The cost of production loss avoided over the period under consideration = N/A
	• ΔCE = The cost of environmental damage avoided over the period under consideration = N/A
	• ΔCF = The cost of averting the total fatalities over the period under consideration = N/A
	• FGD = The factor of gross disproportionality in case of fatality = N/A
	CostRR = CAPEX / life time of the project + yearly OPEX = €80.000/2 + 0 = €40.000/yr
	
	CostRR > BenefitRR hence the proposed mitigation is not ALARP and can be discarded.
	
	A key point to note is that the guidance for estimating hydrogen separation distances is geared towards land based hydrogen filling stations and is focused on distances from the entire hydrogen system to an external receptor. The FERA has assumed that the inventory of the 6 H2 storage vessels are a single unit.
	
	Therefore, adding PFP to structural elements around the H2 storage vessels is considered grossly disproportionate.

CONTROL & EVALUATION	Residual HSSE Risk
	Residual risks remain in connection to the presence of H_2 under pressure in the H2 storage vessels but are designed to ALARP as per BowTie [X].
	Recommendations for Next Project Phase — By
	None
	Requirements for the Operations HSSE-Plan
	None

DRAFT